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IS ECONOMICS BIASED?

A HERETICAL VIEW OF A LEADING THESIS IN SCHUMPETER'S *HISTORY*[1]

I

How far is economics invalidated by ideological bias? How far, in other words, must it be regarded as historically relative? This was one of the great questions which absorbed Schumpeter during the last decade of his life, when he was engaged in expanding his *Epochen* into the monumental *History of Economic Analysis*. One of the most basic contributions of the *History*, at least as Schumpeter himself saw it, was its demonstration that the historical development of 'economic *analysis*', as distinct from that of 'political economy' and 'economic thought',[2] displays a relatively high degree of autonomy with respect to socio-historical facts. 'It is . . . our main purpose', wrote Schumpeter near the beginning of the *History*, 'to describe what may be called the process of the Filiation of Scientific Ideas—the process by which men's efforts to understand economic phenomena produce, improve, and pull down analytic structures in an unending sequence. And it is one of the main theses to be established in this book that *fundamentally* this process does not differ from the analogous processes in other fields of knowledge' (p. 6).

This thesis pervades the whole book and determines its general pattern to such a large extent that it is surprising that it should have provoked so little comment from critics. For example, in none of the

[1] J. A. Schumpeter, *History of Economic Analysis* (1954).

[2] On the distinction between 'economic analysis', 'political economy' and 'economic thought', see Part I of the *History*, *passim*, and particularly pp. 38 *et seq.*

six major review articles, which I have so far read, can it really be said that there is anything like a proper recognition of the importance which the thesis tended to assume in Schumpeter's mind.[3] In most of them, in fact, it is hardly even mentioned. The chief reason for this apparent failure to appreciate the full force of Schumpeter's argument is, I suppose, that the thesis in question is both a very familiar and a very comfortable one, and it is difficult for those of us who have been brought up on it to imagine that anyone should think it worth while to take the great pains which Schumpeter in fact did to establish it. Yet to Schumpeter it was far from being self-evident. It appeared to him to be vitally necessary to defend it against attack—and in particular against the Marxian attack. Schumpeter's attitude towards Marx, indeed, affords the key to the proper understanding of the *History*. In this case, as in so many others, the true significance of the thesis being advanced can be seen only when it is considered in relation to the thesis being opposed.

'What a pity, but at the same time, what a lesson and what a challenge!' (p. 433). This revealing comment by Schumpeter on Marx sums up extremely well his basic attitude towards him. It would be too simple to say that Schumpeter believed that Marx had asked the right questions but given the wrong answers to them, and that it was his own duty to supply alternative answers. One can hardly sum up the life-work of a thinker of Schumpeter's calibre in terms of a single generalisation such as this, although there is undoubtedly an important element of truth in it. It would be more accurate to say of him, with Haberler, that 'all his life he was attracted by the grandeur of the Marxian system'[4]—in particular by Marx's 'vision' of a capitalist economy inexorably developing, always by virtue of its own internal laws, towards its dissolution; but that at the same time he was repelled by certain other aspects of Marx's analysis—in particular by the suggestion that a net surplus taking the form of profit was normally yielded to the capitalist employer even in the absence of monopoly and innovation, and by the associated idea that the capitalist economic system *as such* was racked by exploitation and inherent 'contradictions'. The great force of this attraction and repulsion is clearly

[3] The review articles to which I am referring are those by L. Robbins (*Quarterly Journal of Economics*, February 1955), O. H. Taylor (*Review of Economics and Statistics*, February 1955), J. Viner (*American Economic Review*, December 1954), G. B. Richardson (*Oxford Economic Papers*, June 1955), I. M. D. Little (*Economic History Review*, August 1955), and F. H. Knight (*Southern Economic Journal*, January 1955). Comparison should be made with the brief but fundamentally correct assessment by A. Smithies in *Schumpeter, Social Scientist*, edited by S. E. Harris (1951), p. 21.

[4] *Schumpeter, Social Scientist*, p. 41.

discernible in all Schumpeter's major works. In his *Theory of Economic Development,* for example, as he himself stated, his idea and aim—to construct a theory of capitalist development which relied on forces internal to the system—was exactly the same as that of Marx;[5] but the actual theory of development which he constructed, and in particular the theory of profit which it involved, are probably best regarded as alternatives to those of Marx. Schumpeter liked to call Böhm-Bawerk 'the bourgeois Marx' (*History,* p. 846), and he himself, I think, would not have objected to—and indeed might have been rather flattered by—a similar title.

Where, then, does the *History* stand in this connection? Here too the familiar pattern of attraction and repulsion in relation to Marx is very evident. The attraction is towards the general principles put forward by Marx on the subject of ideological bias;[6] the repulsion is from the Marxian suggestion that the bulk of the so-called 'scientific' economics of modern times is ideologically biased. It is quite true, Schumpeter argues, that economists have to surrender a great deal to the Marxists on the ground that it is ideologically conditioned. 'Political economy' and 'economic thought' must undoubtedly go. But happily there are certain important senses in which 'economic *analysis*' can be shown to remain relatively unscathed. Most notably, the *history* of 'economic analysis' can be shown to display throughout the phenomenon of real scientific progress. Thus, in spite of Schumpeter's concessions to what he regards as the Marxian view, the general argument of the *History* turns out to be very different indeed from that put forward in Marx's own history of analysis, *Theorien über den Mehrwert.* Marx, broadly speaking, argued that the development of the truly scientific elements in political economy continued only up to about 1830, and that thereafter superficiality and apologetics began to predominate. Schumpeter, on the other hand, argues that, in spite of numerous disturbances and detours, we can discern a more or less continuous development of scientific

[5] Schumpeter's statement occurs in his preface to the Japanese edition of the *Theory of Economic Development.* Schumpeter added, however, that this similarity of viewpoint was *not* clear to him 'at the outset'.

[6] Two points should be made here. First, Schumpeter accepts these Marxian principles (which, as will later be shown, he tends gravely to oversimplify) only subject to certain important amendments described on pp. 36-7 of the *History.* Secondly, he uses the term 'ideology', as Marx and Engels themselves often did, to refer to a theory or outlook which consists wholly of illusory elements. Most modern Marxists, however, use the term in a wider sense to include any typical theory or outlook of a particular period or class, into which scientific as well as illusory elements may enter. In the present article the term is used in both senses, but the context should clearly indicate in which sense it is being used in any particular place.

analysis right up to the present day, this development being particularly rapid and striking precisely in the period *after* 1830.

Schumpeter does not of course deny that ideological bias may, and often does, affect the validity of the analyst's results. Ideology may in fact enter 'on the very ground floor': for analytic work 'begins with material provided by our vision of things, and this vision is ideological almost by definition' (p. 42). Fortunately, however, according to Schumpeter, 'the rules of procedure that we apply in our analytic work are almost as much exempt from ideological influence as vision is subject to it'; and these rules tend, given time, 'to crush out ideologically conditioned error from the visions from which we start' (p. 43). Here, unfortunately, Schumpeter's manuscript breaks off, and the account which he might possibly have given of the various other ways in which ideology may enter into analysis is missing. But the general tenor of his views on the subject is clear enough. He is particularly concerned to combat any 'sterile pessimism concerning the "objective validity" of our methods and results' (p. 43). Not only are there many items in our box of tools that are, and are known to be, ideologically neutral, or that can be shown to be so in spite of popular belief to the contrary (p. 44); not only can a judicious use of the rules mentioned above safeguard us individually, at least up to a point, against ideological bias; but also—and here is the thesis I wish to examine—these rules are in actual fact automatically applied in the historical development of economic analysis, so that over time, notwithstanding all the inhibitions, detours and setbacks to which this development is manifestly subject, it is possible to speak of real scientific progress in our field. Historically speaking at any rate—in its temporal flow, as it were—economic analysis does not show any serious signs of ideological infection. The clear implication of all this for present-day analysis is that 'if complacency can ever be justified, there is much more reason for being complacent today than there was [a century] or even a quarter of a century ago'.[7]

No one will be prepared to deny that there are indeed certain spheres of economic analysis as Schumpeter defines it—statistics, for example—of which this thesis can be held to be essentially true. Doubts begin to creep in, however, as soon as we turn to 'pure theory' in Schumpeter's sense. Even here, of course, there are certain concepts, *e.g.* elasticity, whose emergence was obviously induced much more by logical than by social pressures. But if we consider the really central propositions of 'pure theory' we are on much less certain ground. This applies with particular force to the theory of value.

[7] Schumpeter, *American Economic Review*, March 1949, p. 345.

Since 'the problem of Value must always hold the pivotal position, as the chief tool of analysis in any pure theory that works with a rational schema' (*History*, p. 588), it was vitally necessary for Schumpeter to establish his thesis with special reference to the history of value theory. It is no accident, then, that the majority of Schumpeter's illustrations of the thesis, in the body of the *History*, relate to value theory; and it is around this aspect of the problem that my own criticisms of Schumpeter will largely turn.

It is in the first of the three main historical sections, dealing with the period from the beginnings up to about 1790, that the real groundwork of Schumpeter's thesis is laid. So far as the later historical sections are concerned, the majority of present-day Marxists (in so far as the present writer's opinion can be regarded as representative)[8] would probably have little quarrel with the *main* propositions which Schumpeter lays down concerning the actual trends of development—although they would be largely unsympathetic towards many of the valuations which Schumpeter bestows on these trends and towards the strong teleological strain which is so apparent in his account.[9] But in relation to the period up to 1790 the Marxian view of what actually happened is very different from Schumpeter's.

II

Most Marxian economists would probably begin by dividing this period into three stages. First, there was the Aristotelian—Scholastic stage, in which the 'value' of a commodity was usually identified with the price at which it *ought to* sell, this being in turn identified with the costs (notably labour costs) normally involved in its production. Second, there was the Neo-Scholastic—Mercantilist stage, in which 'value' came to be widely identified with the price at which a commodity *actually did* sell, and was conceived to be determined by the interplay of supply and demand, with the main emphasis laid on the

[8] The prevalence of misunderstandings concerning the character of the Marxian method leads me to emphasise here that while Marxian economists naturally hold certain basic propositions and postulates in common (just as Marshallians or Keynesians do) there is still plenty of room for differences of opinion among them. What Keynes said of 'the Theory of Economics'—that 'it is a method rather than a doctrine'—applies with special force to Marxism. Marxism is not a substitute for analysis of the facts but a method of analysing them, and it is precisely through the differences of opinion which arise when this method is applied to the analysis of the facts that Marxism itself is developed. Marxists would add, however, and insist very strongly, that their theory is a guide not only to analysis but also to action.

[9] I am mainly referring here to Schumpeter's tendency, noted by G. B. Richardson (*op. cit.*, p. 142), 'to regard the general equilibrium system as the divine event to which the whole creation moves, and to judge performances according to whether they hastened or retarded its arrival'.

demand side. Third, there was the classical stage (in Marx's sense),[10] in which 'value' gradually came to be identified with the competitive equilibrium price (which was taken to be equal to the cost of production, including 'normal' profits), and was conceived—at least towards the close of the stage—to be determined ultimately by the quantity of embodied labour. This scheme obviously suffers from all the defects which are necessarily involved in any such attempt at stadial analysis, and from certain others as well; but it does at any rate provide a framework within which the developments concerned can be seen in what I believe to be their correct perspective.

Schumpeter's approach, however, is quite different. Speaking very broadly, he tends to write as if the characteristics of the work of the second stage which I have just distinguished were more or less typical of those of the period as a whole, at least up to the time of Adam Smith. He argues that the scholastic doctors, working from Aristotelian roots, had developed an analysis of value and price in terms of 'utility and scarcity' which 'lacked nothing but the marginal apparatus' (p. 1054, cf. also p. 98); that this analysis 'went on developing quite normally right into the times of A. Smith' (p. 1054); that 'it was the "subjective" or "utility" theory of price that had the wind until the influence of the *Wealth of Nations*[11]—and especially of Ricardo's *Principles*—asserted itself' (p. 302); and, in fact, that the salient feature of the analytical work of the whole period up to 1790 was actually the development of the elements of what Schumpeter calls 'a full-fledged theory of demand and supply' (p. 98). In relation to the first stage, Schumpeter seems to me to overestimate the extent to which Aristotle and Aquinas actually *identified* the 'just price' with the competitive equilibrium price.[12] And, in relation to the third stage,

[10] Marx regarded the period from Petty to Ricardo in Britain (and from Boisguillebert to Sismondi in France) as the period of the development of a 'classical' political economy which, although exhibiting certain important defects, nevertheless investigated scientifically 'the real relations of production in bourgeois society'. See *Critique of Political Economy* (Kerr edn.), p. 56, and *Capital*, Vol. I (Allen and Unwin edn.), p. 53, footnote. Thus the 'classical' stage in fact extends beyond 1790, where Schumpeter made his break.

[11] Even in the case of Smith, according to Schumpeter, the best piece of economic theory which he turned out ('the rudimentary equilibrium theory of Chapter 7') actually 'points towards Say, and, through the latter's work, to Walras' (p. 189).

[12] There was indeed a connection between the 'just price' and the competitive equilibrium price, but it was much less direct and conscious than Schumpeter's argument implies. Schumpeter suggests that Aristotle took competitive equilibrium prices as standards of commutative justice (p. 61), and that Aquinas similarly identified the 'just price' with the competitive equilibrium price (p. 93). It would be more correct to say that Aristotle and Aquinas took prices proportionate to producers' costs (notably labour costs) as standards of commutative justice, and that these standards were *ultimately* (but not necessarily consciously) derived from their observation of the fact

he underestimates the importance of the typically 'classical' developments, in respect of both their quantity and their quality.

On the quantity side, this is perhaps best shown by his attitude towards the more or less primitive expressions of the labour theory of value (and associated ideas) which are frequently to be found in the pre-Ricardian literature. Apparently taking 'all or nothing' as his slogan, he virtually rejects the idea that a 'labour theory of value' is to be found either in Petty or in Smith; he omits to consider Franklin and the author of *Some Thoughts on the Interest of Money in General* in this connection; and he seriously underestimates the extent to which a large number of other writers—Boisguillebert, Mandeville, Locke, Hume, Gervaise and Tucker, for example—popularised certain concepts which helped substantially to form the climate of opinion in which the mature labour theory of value was later to flourish. But more important than this is his underestimation of the scientific *quality* of the 'classical' developments in value theory. In so far as he recognises their existence, he obviously regards them as having inhibited scientific advance rather than promoted it. One of the chief villains of the piece, according to Schumpeter, was the idea that the 'normal' or equilibrium price is determined by cost and the market price by supply and demand. This is described as a 'superficial, and, as the later development of the theory of value was to show, misleading formula' (p. 220). And the idea that relative equilibrium prices are ultimately determined by relative quantities of embodied labour, which Ricardo was to develop into the very basis of his system, seems to be regarded by Schumpeter as little more than a simple analytic error.

Why, then, were these new 'classical' ideas seized upon with such eagerness and developed by men of undoubted intellectual ability?[13] They were seized upon and developed precisely because they were regarded as *scientifically* superior to the ideas current in the second stage. At the time when men first began to think seriously about the prices at which commodities actually sold (as distinct from the prices at which they ought to sell), the only useful proposition that it was really possible to make about these prices was that they were determined by the interplay of supply and demand. So long as there was

that, in the real world, exchange ratios tended, in the absence of monopoly, towards equality with ratios of producers' costs. Thus when Aristotle and Aquinas spoke of the 'just price' of a commodity they were not actually *thinking* of its competitive equilibrium price, which is what Schumpeter suggests. Our ideas about justice certainly come to us from earth and not from heaven, but we are not always aware of this fact.

[13] A number of the sentences in this paragraph are reproduced more or less verbatim from my *Studies in the Labour Theory of Value* (1956).

no very marked tendency for the amount of 'profit' earned by a producer to bear a reasonably regular relationship to the amount of 'capital' which he employed, it was difficult to make any general statement about the price of his commodity other than that it would usually exceed what Smith called 'prime cost' by an increment ('profit' or 'gain') which varied in each individual case according to the state of supply and demand in the market. To the merchant of the sixteenth and seventeenth centuries, interested mainly in the day-to-day prices of a very limited range of goods, such a 'theory of value' would appear more or less adequate, since supply and demand could reasonably be regarded, in the context of this particular problem, as 'independent' determining factors. But it was scarcely capable of serving as the basis for forecasts of any great degree of generality. Once the phenomenon of a normal or 'natural' rate of profit had begun to manifest itself on a sufficiently wide scale, however, it became possible to put forward a much more useful general principle concerning commodity prices. Commodities, it could now be said, tended under competitive conditions to sell at prices equal to 'prime cost' plus profit at the 'natural' rate. A situation in which this 'natural' rate of profit was being earned, so that there was no tendency for firms either to enter or to leave the industry, could then be defined as a situation of equilibrium, in which supply could be said to 'balance' or 'equal' demand. This principle, however, applied only to equilibrium prices under competitive conditions: so far as other prices were concerned, no scientific advance was possible over the old supply-and-demand explanation.[14] To the economists of (roughly) the first half of the eighteenth century, interested mainly in the average prices of the relatively small group of goods produced on a capitalist basis and sold under competitive conditions, a cost-of-production 'theory of value' founded on this principle would appear more or less adequate, since the level of the various rewards into which the cost of production ultimately reduced itself—rent, wages and profit—could plausibly be conceived as 'independent' determining factors. But as the sphere of operation of capitalist production extended, and the

[14] Those who accepted this principle naturally tended to look upon any reversion in discussion to the terms of the old supply-and-demand explanation as more or less obscurantist. But this definitely did not imply that they were blind to the fairly obvious fact that it was 'supply and demand' which actually fixed the equilibrium price at the level defined in the principle. Schumpeter's suggestion (pp. 600-1) that Ricardo and Marx did not observe that their theories of value 'presuppose that supply and demand do their work' can readily be refuted by reference to a dozen passages in the work of both of these economists—and has in fact been so refuted, at least in the case of Ricardo, by several commentators. (See, *e.g.*, Robbins, *op. cit.*, pp. 13-4, and Viner, *op. cit.*, pp. 904-5. In the case of Marx, see, *e.g.*, *Capital*, Vol. III, Ch. 10.)

notion of the general interdependence of the various elements of the economic system as a whole took firmer hold of men's minds, it became evident that these ultimate constituents of the cost of production could no longer be treated as 'independent' determinants of the prices of commodities; they would themselves be partly dependent upon these prices. Thus economists who were interested in dealing with broad fundamental problems concerning 'the nature and causes of the wealth of nations' began to look for a new value-principle—some 'unifying quantitative principle', to use Mr. Dobb's phrase,[15] —which would serve as a 'constant' capable of determining not only the equilibrium prices of commodities but also the equilibrium prices of land, labour and capital.[16] The classical economists gradually came to believe—or at least to recognise instinctively—that a value theory of this type was required before political economy could be transformed into a real science. And can it really be said that they were misled? The pattern of development which I have just been describing is quite a familiar one in the history of science; and, whatever may be thought of the actual value-principle which finally emerged in the classical period, it must surely be conceded that it emerged as the result of enquiries which, at least when disentangled from their popular background, were in the best traditions of scientific advance.

But why was value anchored to the quantity of embodied labour rather than to some other 'constant'? Partly, no doubt, for the negative reason that there did not appear to be anything else to anchor it to, which would fulfil the requirements of a theory of value as the classical economists were coming to understand them. ('Utility' was of course available by then; but the fact that the long-term equilibrium prices of commodities normally remained unaffected when purchasers' estimates of their utility altered seemed to the classical economists to weigh conclusively against its use.) There is, however, a much more important reason than this. The emergence of the labour theory of value was closely associated with the emergence of the idea that the 'chief cement', as Harris put it,[17] that connected men together was the simple fact that they lived by 'betaking themselves to particular arts and employments'[18] and mutually exchanging the products of these separate labours. By engaging in the production of commodities for the market, men in effect *worked for one another*; and it was in terms of this basic socio-economic relation between men, as separate but mutually interdependent producers of commodities,

[15] *Political Economy and Capitalism* (1937), p. 5.
[16] Cf. Dobb's discussion of this whole point, *ibid.*, pp. 8-10.
[17] J. Harris, *An Essay upon Money and Coins* (1757), p. 15, footnote.
[18] *Ibid.*

that their relationships in the field of exchange ought properly to be explained. The value relationship between commodities which manifested itself on the market, in other words, was conceived as reflecting a fundamental social relationship between men and men in the field of production. Thus the exchange of commodities was regarded as consisting in essence of the exchange of the respective quantities of labour which their producers had employed in producing them ; and the relative ' values ' of different commodities—their respective ' social weights ', to use Marx's expression—were regarded as being ultimately determined by the relative quantities of labour which society found it necessary from time to time to allocate to their production. The use of embodied labour as the value-constant was in effect a generalised expression of the view (whether consciously formulated or not) that political economy, if it was to be truly scientific, must start from, and on no account abstract from, the real relations between men and men in the sphere of production. This view is of course debatable, and Schumpeter himself strongly dissented from it ; but that is no excuse for his apparent failure to appreciate its relevance to the question of the development and scientific quality of value theory in the classical period.

If we leave such facts as these out of consideration, it is easy enough to proceed as Schumpeter does—to minimise the importance of most of the typically ' classical ' developments in the history of economic science, to undervalue Smith's contributions to analysis, and to leave Ricardo, as it were, out on a limb. The post-Ricardian developments, which Schumpeter correctly sees as constituting in essence, almost from the beginning, a *rejection* of the really basic Ricardian postulates, can then be quite plausibly described as a return to ' the historical line of economists' endeavours ' after a relatively brief Ricardian ' detour '.

But there were two more tasks to be performed, in relation to the post-Ricardian period, if the Schumpeterian thesis was to be consolidated and the Marxian thesis finally rejected.

III

Marxists, in their interpretations of post-Ricardian developments, have drawn particular attention to that general tendency towards abstraction from the relations between men and men in production which was characteristic of the period as a whole and of which the rejection of the labour theory was one of the most striking expressions. In addition, they have suggested that certain specific theories which emerged during the period—notably the new theories of value and

distribution—embodied important elements of ideological illusion. Schumpeter therefore felt obliged, in the first place, to prove that the abstraction which took place from the relations between men and men in production was scientifically justified, and, in the second place, to defend the new theories against the charge that they were ideologically tainted.

The general tendency towards abstraction from the relations between men and men in production manifested itself in a number of different ways. One of its most noticeable manifestations was the retreat from the idea that a scientific analysis of the distribution of income must start from the relations between the social classes in production. There was a 'prevailing tendency', as Schumpeter notes, 'to get away from . . . the class connotation of the categories of economic types' (p. 552). It is upon this tendency that Schumpeter concentrates in his consideration of the problem. Non-Marxist economics, he argues, was bound increasingly to regard this 'class connotation' as 'a blemish due to the survival of pre-scientific patterns of thought'. This new view, he says,

> 'was the inevitable consequence of analytic advance that made more and more for a clear distinction of the purely economic relations from others with which they are associated in reality. In analysing economic phenomena, categories other than those suggested by the class structure of society have proved more useful, as well as more satisfactory, logically. This does not involve overlooking any relevant class-struggle aspects, or simply class aspects, of the relations investigated. All it does involve is greater freedom for all the various aspects of reality to assert their rights' (p. 551).

But surely the emphases here are unduly emotive. What could be more useful and 'scientific', it might at first sight be thought, than to make 'a clear distinction of the purely economic relations from others with which they are associated in reality'? But there is no fixed boundary line between 'purely economic' relations and others: if an analyst distinguishes one set of relations which he labels 'purely economic' from another set which he describes as merely 'associated in reality' with the first, all he is really doing is to say that in his opinion an analysis of basic economic phenomena couched in terms of the first set of relations is quite adequate, and that no account, or relatively little account, need be taken of the second set. And this, of course, is a proposition which requires to be proved on every occasion that such a distinction is made. Then again, who would not want to adopt an approach which did no more than allow 'greater freedom for all the various aspects of reality to assert their rights'? But surely what was involved in the particular historical development which we are considering was not simply a sort of extension of democracy, but rather the

dethronement of certain 'aspects of reality' which had formerly been regarded as exercising a fundamental determining influence, and their supersession in this position by others. The old idea that the problem of distribution had to be considered in terms of the relations of production gave way to the idea that it could be adequately considered in terms of the simple fact that a firm needs certain 'scarce factors' in order to produce.[19] And, naturally, it cannot be assumed without proof that this constituted a scientific advance. Schumpeter would not, I think, have wished to dissent from this—certainly it seems to be implied in his statement in a note to the passage just quoted that 'the proof of this pudding is, of course, in the eating'—but, both here and elsewhere, there are expressions which suggest that he tended to underestimate its importance.

The fulfilment of the second task mentioned above is one of Schumpeter's major preoccupations throughout the latter part of his book. On many occasions he pauses to comment upon the absurdity of regarding certain theories developed in the post-Ricardian period as ideologically conditioned. Since these comments are often specifically oriented against what Schumpeter regards as the Marxian view of ideology, it is necessary to emphasise that Schumpeter frequently tends to oversimplify that view. Marxists, for example, do *not* say that the theories in question were deliberately excogitated for apologetic purposes; or that they were nothing more than reflections of the class and income positions of the particular individuals who put them forward; or that they did not tend to develop under their own steam, as it were, once they had been put forward. The process by which ideologies arise on the basis of the material life of society, and develop along with it, is always an extremely complex one, the details of which can never be postulated *a priori*; and to explain the development of orthodox economic theory since Ricardo on the basis of propositions such as those just stated would be almost as much opposed to the spirit of Marxism as it would be to deny that orthodox economic theory, *in essence*, does in fact constitute part of a class ideology in which illusory elements tend to predominate.

Let us take two examples of Schumpeter's attitude to this question. First, consider his treatment of 'the victory of the marginal utility theory'. Here Schumpeter is quite uncompromising: the marginal utility theory is alleged to be a piece of purely scientific analysis with no political connotations whatsoever. 'Economic theory', writes Schumpeter, 'is a technique of reasoning; . . . such a technique is neutral by nature and . . . it is a mistake to believe that something is

[19] Cf. *History*, pp. 558-9.

to be gained for socialism by fighting for the Marxist or against the marginal utility theory of value' (p. 884). Political liberalism, says Schumpeter, in so far as the theorists concerned actually espoused it,

> 'had nothing to do with their marginal utility theories. Marxists no doubt believed that these had been excogitated for purposes of social apologetics. But the "new" theories emerged as a purely analytic affair without reference to practical questions. And there was nothing in them to serve apologetics any better than had the older theories. In fact, the contrary would be easier to maintain (compare, *e.g.*, the equalitarian implications of the "law" of decreasing marginal utility); and it was "bourgeois" economists who developed, during that period, the rational theory of the socialist economy . . . ; it was Marshall, Edgeworth and Wicksell who reduced the doctrine that free and perfect competition maximises satisfaction for all to the level of an innocuous tautology' (p. 888).

Here Schumpeter gravely misconceives the nature of the Marxian thesis. As I have just indicated, Marxism does not interpret ideological illusion in terms of conscious deception; and while it does indeed 'believe that something is to be gained for socialism by fighting for the Marxist or against the marginal utility theory of value', this is only because it also believes that something is gained for socialism whenever something is gained for science. Nor is the Marxian theory of ideology shaken, as Schumpeter appears to think, by the fact that it was 'bourgeois' economists who established the so-called theory of socialism and criticised the doctrine of maximum satisfaction. Marxism does indeed argue that ideologies are developed on the basis of a given social structure, and that, broadly speaking, they serve the interests of one or another social class. But it also emphasises that in so far as an ideology contains illusory elements, contradictions between these elements, on the one hand, and logic and the facts, on the other, are bound to emerge, and that it is precisely by means of the ideologists' attempts to resolve these contradictions that the ideology is developed and elaborated. These attempts, however, do not necessarily or automatically bring about a reduction in the proportion of illusory to scientific elements in the ideology (as Schumpeter tended to assume): as we shall shortly see, they may well have the opposite effect on some occasions.

A fully-fledged Marxian critique of the marginal utility theory of value would concentrate, I suggest, mainly upon the fact that the popularisation of that theory set the seal upon the incorporation of certain important elements of ideological illusion into bourgeois economic theory. These elements were of course by no means entirely new: if we compare the theories of the economic process adopted by the leaders of the 'marginal revolution' with those adopted by most

of the earlier post-Ricardian writers, or indeed with those adopted by the whole line of writers whose endeavours lay within the main historical stream *as Schumpeter conceived it,* we will certainly agree with him that neither the marginal utility theory nor any other conceptual creation of the period 'points toward a new fact or a new slant' (p. 892). If, however, we compare the theoretical systems of (say) Jevons, Walras and Menger, with those of the classical economists as defined above, it will be precisely the presence of a 'new slant' which attracts our attention, and it will be in the marginal utility theory of value that we will find the most obvious and most general expression of this 'new slant'. The point is that the theory of value with which an economist begins usually embodies some sort of *general principle of causation* which he believes will be useful in the explanation of economic reality. And the principle of causation embodied in the marginal utility theory is radically different from that embodied in the labour theory. What we must start with, the marginal utility theory says in effect, is not the social relations between men and men in production, as the labour theory implied, but rather the mental relation between individuals and finished goods. The basic illusion which the marginal utility theory embodies, the Marxian critique would say, is that an explanation of economic reality which abstracts from the social relations of production is more 'scientific' than one which does not. The critique would not stop there, of course: it would also consider, for example, such problems as that of the extent to which the victory of the theory was due to its usefulness in connection with the so-called 'scarcity problem' which was then beginning to emerge to prominence in the real world; the extent to which the anxiety of certain writers (*e.g.* Wieser and J. B. Clark) to combat Marxism influenced the direction in which the theory developed; and the extent to which this direction was also influenced by the fact that the theory could be used plausibly to demonstrate that free exchange maximised satisfaction. But the really basic point to be made, I think, is that which I have just been elaborating.

IV

As our second example of Schumpeter's attitude we may take his view that 'the transition from the marginal utility theory of value to a theory of value based upon the concept of marginal rate of substitution was ideologically neutral in the sense that either can be shown to be equally compatible with any ideology whatsoever' (p. 44). Those who accepted the latter theory in preference to the former, says Schumpeter, 'have done so for purely technical reasons that are completely irrelevant to any ideology of economic life' (*ibid.*). So far as ideologically

relevant issues are concerned, the replacement of the labour theory by the marginal utility theory, the replacement of the latter by the indifference curve approach, and the replacement of the indifference curves by a simple consistency postulate are all on a par.[20] This is a proposition which Schumpeter apparently regards as self-evident and does not feel himself obliged to prove.

Now Marxists would be quite happy to concede that Professor Hicks, say, in writing *Value and Capital,* was not actuated by a sinister desire to come to the defence of monopoly capitalism.[21] They would also agree wholeheartedly that the marginal utility theory and the indifference curve approach are 'equally compatible with any ideology whatsoever' *in the particular sense emphasised by Schumpeter*—namely, that one cannot *in good logic* draw political or ethical conclusions from them; and they would willingly join in a campaign to persuade their colleagues to frame some of their theoretical propositions regarding value and distribution in such a way as to discourage rather more strongly the drawing of such conclusions. But these two concessions would by no means imply agreement with the thesis that the transition in question was 'ideologically neutral' *in Marx's sense.* For the fact that the theories concerned are 'non-political' in the very limited sense just described does not necessarily mean that considerations of 'politics' in a wider sense did not influence the transition from one to the other.

The essential point seems to be this. The marginal utility theory was put forward with the aim of supplying a 'unifying quantitative principle' which could replace the labour theory. In the course of the development of the marginal utility theory there emerged certain 'contradictions' of the type noted above. For example, doubts arose as to the measurableness of utility; the claims of realism clashed with those of relevance over the question of whether the utility of every commodity should or should not be regarded as a function of the quantity of that commodity alone; it was suggested that the law of diminishing utility had equalitarian implications; and so on. Naturally, various attempts were made to resolve these contradictions. Now these attempts might *conceivably* have led in the direction of some sort of rehabilitation of the classical approach to the value problem, with its implied emphasis on the fact that the social relations of production are of basic importance in the explanation of economic phenomena. But in actual fact they led in the opposite direction,

[20] *American Economic Review,* March 1949, p. 352.

[21] They would not, however, agree with Schumpeter that Professor Hicks's book could not be improved by the introduction of sociological considerations (cf. *History,* p. 785).

towards an even greater degree of abstraction from these relations. The main tendency of the last half-century has been towards an explanation of economic phenomena in terms of a general theory of equilibrium values in which the concept of utility is superfluous and for the purposes of which even the indifference curve analysis is said to assume more than it is 'necessary and comfortable' to assume (*History*, p. 1067). The only postulate we really need, it is now alleged, is that in a given price-and-income situation 'everybody chooses to buy (or sell) in a uniquely determined way' (*ibid.*). Once we have arrived at this stage, the marginal utility theory begins to appear as a sort of 'ladder' (p. 918) leading up to the general equilibrium system, and the indifference curve analysis as 'after all but a midway house' (p. 1066) on the road towards it.

The Marxist would claim that the general equilibrium theory represents not only a further retreat from the relations of production, but also to some extent a retreat from science itself. No doubt it is important that we should always recognise that there is a significant sense in which everything can be said to be determined by everything else; but when a discipline voluntarily decides to say no more than this, and to give up the attempt to find some factor in a given total situation which can be postulated as 'independent' (in something more than a merely formal sense) and regarded as a basic determinant of the situation, it does seem to me that this decision savours not so much of science as of its negation. This could not be said of the introduction of the marginal utility theory, which sought merely to replace one particular 'constant', which the classical economists had inserted as the independent determinant in their equational system, by another which was also postulated as independent. The value problem, according to the Marxian view, was still scientifically posed, even if it was not scientifically answered. In so far as the indifference curve analysis was in fact a 'midway house' on the road towards the general equilibrium theory, then, the replacement of the marginal utility theory by the indifference curve analysis cannot properly be regarded merely as the substitution of one tool for another. It marked an important stage in the development towards that almost exclusive preoccupation with form at the expense of content, which characterises so much of value theory today. And this development towards formalism in economic theory, like the similar developments taking place in art, literature and music, can hardly be said to be 'ideologically neutral'. Marxists are surely not very far astray when they look for the *ultimate* causes of such developments as these in the important changes which

have occurred in socio-economic relationships during the present century.

V

To sum up, then, it seems to me that Schumpeter by no means succeeds in demonstrating that the history of economic analysis displays the phenomenon of real and relatively uninterrupted scientific progress. His discussion of the period up to Ricardo is marred by an ante-dating of the beginnings of the 'supply-and-demand' analysis, and, more important, by a serious underestimation of the extent and the scientific quality of the classical innovations. His discussion of the post-Ricardian period is marred by a tendency (as Mr. Little puts it) 'to over-assess the importance of sheer techniques, and of rigour and generality—things which are unassailable on a logical level';[22] and also, it may be added, by a tendency to regard a pure economic logic which abstracts from the relations of production, as *ipso facto* more scientific than a political economy which insists on starting from them. So far as the Marxian thesis is concerned, Schumpeter succeeds in disposing only of an extremely 'vulgar' version which is rarely met with today, and which has no real right to be called Marxian at all. To say this, however, is not at all to detract from the great erudition and subtlety which distinguish Schumpeter's analysis, or to deny that the *History* will remain for many years to come perhaps the greatest single quarry of ideas available to workers in this fascinating field.

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[22] *Op. cit.*, p. 92.

ELECTRICITY IN THE NORTH OF SCOTLAND

THE North of Scotland Hydro-Electric Board was instituted by a 1943 Act of Parliament to develop electricity from water power in the Highlands and to distribute electricity in the West Highlands and Islands. Its powers were enlarged in 1947 by a further Act of Parliament by which its responsibilities for the generation (by any means) and the distribution of electricity were extended to include the whole of that part of Scotland which lies north and west of the Firth of Tay and the Firth of Clyde. It thus now controls the large steam stations of Aberdeen and Dundee.

The February 1956 issue of the *Scottish Journal of Political Economy* contained an article[1] dealing with the problem of whether or not the North of Scotland Hydro-Electric Board is right in the policies it carries out. The article is of interest not only for the data it contains, but also because of its inferences in regard to the 'problem'; unfortunately, these inferences may lead to a complete misunderstanding of the real position. The facts are that 'policies' were laid down in the original 1943 Act of Parliament, which set up the Board. It is interesting to examine what that Act said about the duties of the Board and compare them with that part of the 1947 Act which established the British Electricity Authority. The 1943 Act said:

> 'The Board shall be responsible for initiating and undertaking the development of all further means of generation of electricity by water power . . . and it shall be the duty of the Board so far as practicable to provide supplies of electricity required to meet the demands of ordinary consumers and also to collaborate in the carrying out of any measures for the economic development and social improvement of the North of Scotland district.'

On the other hand, the duty of the British Electricity Authority (now the C.E.A.) is 'to develop and maintain an efficient, co-ordinated and economical system of electricity supply'. The difference is quite apparent and is further underlined by the authority given to the North of Scotland Board not only to supply electricity to those within its own area desirous of a supply but to sell any balance to the Grid outside its own area. The Act of 1947 made more certain the intention of the 1943 Act to supply very sparsely populated areas within the enlarged area, so that they could be supplied as adequately as possible with electricity, even if it became necessary to produce it by means other than water power.

[1] D. L. Munby, 'Electricity in the North of Scotland', pp. 19-43.

It will be seen from the foregoing statements that what Mr. Munby, the writer of the article, calls the ' policies of the Board ' are in fact policies of Acts of Parliament, the Board's function being to give effect to these policies.

The point might arise as to what a Board should do, if they found that their instructions, in their opinion, were unworkable. Obviously it will never arise unless, over a term of years, the income the Board acquires is unable to meet all its expenditure, which must include the interest and amortisation within a reasonable period of the loans contracted. Consequently it is not the Board's actions Mr. Munby impugns but those of Parliament. Mr. Munby is inclined to question the underlying principle of the Acts, and, in addition, casts grave doubts on the economics of the developments carried out by the Board. The initial problem therefore is whether Parliament was justified or not in what it did.

The intention of Parliament was to ensure that electricity supplies would be made available throughout an area which could not by any other means get them. The method of achieving this was by the development of the North of Scotland's hydro-electricity potentiality in such a way that its cost, when compared with steam or other known methods of electricity generation, would provide a sufficient margin of profit to offset losses on unremunerative consumers. If this general intention is accepted, then the only criticism which can be directed against the Board is whether the hydro schemes are in fact producing power at a sufficiently low cost to provide the necessary margin. If this policy is not accepted, then it follows that unless a community can pay for all the cost incurred on its behalf, and requires no support from other communities, it should not receive a supply at all. This would mean that many of the amenities which are now enjoyed by the country at large would be restricted to areas where there were large aggregations of people ; for example, only those parts of the country would enjoy railway facilities in which the part of the system which served them paid its way. The country is now witnessing the demise of sections of railways in the North of Scotland and elsewhere because of this fallacious policy, and, if it continues much farther, the time may come when perhaps only services between such large centres as London, Edinburgh and Glasgow will remain. If this were to apply in other fields as well the postal service would not continue to be enjoyed as it is ; and, worse still, no university or college could get a Government grant unless the ratio and standing of its staff to students was as good as, say, London, Oxford or Cambridge. But accepting that the decision taken by Parliament was justified and must be carried out, then the Board can be criticised only if the hydro schemes are not

in fact producing power at a sufficiently low cost to sell it at a price which in fact is substantially less than would have been possible in any other way, and moreover provides the margin of profit necessary to offset losses on unremunerative consumers.

It is possible to demonstrate from the figures, mostly given in Mr. Munby's article, not only that the water power developed by the Hydro Board is cheaper than could be produced by any other means but a great deal cheaper than that given by him ; and also that what is being developed is well below current steam costs and even the most optimistic of nuclear costs.

TABLE I

COSTS OF GENERATION AT HYDRO-ELECTRIC AND COAL-FIRED STEAM STATIONS

(Pence per unit generated)

Type of generation	Annual load-factor				
	15%	30%	45%	60%	90%
Hydro-electric—70-year life	1·18	0·80	0·75	0·80	—
30-year life	1·55	1·03	0·98	1·06	—
Coal-fired steam stations[1]	1·76	1·10	0·88	0·77	0·66

[1] Costs given by Mr. Munby including 15 per cent. for extra North of Scotland fuel costs but excluding his suggested 50 - 75 per cent. additional fuel costs.

TABLE II

COSTS OF GENERATION AT HYDRO-ELECTRIC AND NUCLEAR STATIONS

(Pence per unit generated)

Type of generation	Annual load-factor				
	15%	30%	45%	60%	90%
Hydro-electric—70-year life	1·18	0·80	0·75	0·80	—
30-year life	1·55	1·03	0·98	1·06	—
Nuclear—present-day estimates	—	1·62	1·07	0·80	0·57
future optimistic estimates	—	1·24	0·83	0·63	0·42

In comparing costs of generation, it is necessary that they should be compared on an equivalent basis. Mr. Munby has extracted many figures of cost from the *Reports* of the Board and the Central Electricity Authority, and has made certain comparisons. He has not entirely succeeded in avoiding the pitfalls which arise when the intricacies of load factors have to be negotiated. What he has overlooked is that the substantial difference between the cost of producing hydro power at low load-factor and the cost of producing power at the same load-factor by steam enables the Board to sell low load-factor power at a competitive price to the other Authorities outside its area. In this way the average cost of supplying power is reduced to consumers within its own system at the load-factor they require.

A much more accurate comparison than Mr. Munby uses can be obtained if it is considered what the energy consumed in the North of Scotland would have cost if hydro power had not been used, and what the production cost actually was for the Board's consumers. The only alternative means of producing electricity open to the Board was generation by steam. The equivalent capacity could have been produced by adding new stations to those already existing at Aberdeen and Dundee. This would have created a mixture of high and low load-factor plants such as is owned by the Central Electricity Authority but with the following differences:

(i) the size of the stations would have been smaller with correspondingly poorer efficiency at all levels;
(ii) coal would have been somewhat dearer; and
(iii) the Board's load-factor is less than that of the Central Electricity Authority.

Therefore, if steam stations had been built in the Highlands, the total production cost could not have been less than the figure of 0·80d. per unit given by Mr. Munby, in Table VI of his article,[2] as the C.E.A.'s cost of production for 1954. Adding 0·06d. to the above figure, to take account of the 15 per cent. suggested in Mr. Munby's paper for the higher cost in the North of Scotland of fuel and the other factors mentioned, gives a price of 0·86d. as being the cost of production if there had been no hydro electricity.

The Board's actual cost of generation from all sources in 1955 was 0·74d. per unit. This is substantially cheaper than steam would have been; but that is not the only advantage enjoyed by the Highlands. All generation cost the Board £4·58 m. in 1955; but the whole of this was not paid for by consumers in the Board's area. After deducting a share of transmission, management, rates, etc., from the income received from bulk sales, it cost the Board only £3·60 m. to

[2] *Op. cit.*, p. 30.

produce the energy needed by its own consumers, and this is equivalent to 0·66d. per unit generated. Mr. Munby's Table VI therefore requires to be altered, and if the costs of producing energy for the Board's own consumers are considered, it is clear that these are much lower than those of the C.E.A. and substantially lower than would have been possible if steam generation had been used instead.

The Board's load-factor of about 38 per cent. is well below the national load-factor of about 48 per cent., and therefore the Board's costs of production are clearly much cheaper than would have been possible in any other way. There is no evidence that the Board's cost of production is rising steeply as a result of new hydro schemes coming into service or on the way. On the contrary, the price per unit sold to consumers in 1955 increased over that in 1949 by only 4·5 per cent. for domestic consumers, 6·2 per cent. for farms and 3·4 per cent. for commercial consumers compared with 8·2 per cent., 8·6 per cent. and 5·1 per cent. respectively in the rest of the country.

Altogether, when Mr. Munby made his review there were ten schemes under construction which had not contributed to the Board's output. They have a capacity of 277 megawatts and will produce 939 m. units per annum. At present prices they will cost, when they are all finished in two or three years' time, £68 per 1,000 kilowatt-hours per annum which compares with an average of £61 for all the hydro schemes put into service since the war.

The trend is slightly upwards, but is markedly less than the present rate of rise in coal prices. The cost of coal controls not only the fuel element in steam power production but is ultimately reflected in the cost of the generating plant itself because of the great amount of steel which goes to make up a steam station.

In Fig. 3 of a paper read by Hunter and Mountain before the Institution of Civil Engineers in Session 1942-43, comparative hydro and steam costs, in the form annual costs per kilowatt of maximum demand plotted against the load-factor, were given. These curves have been brought up to date by plotting the cost per unit, adjusted to 1956 construction costs, of all the Board's post-war schemes and the cost of steam units at the prices given by Mr. Munby on p. 33 of his article. The result is shown in Fig. 1 and in Table I. At all load-factors, up to say 60 per cent., hydro plant is more favourable. The hydro costs have been arrived at by using the universally-accepted long-term sinking-fund periods for dams, rock tunnels and similar hydro-electric works. For comparison, however, the cost has been re-calculated on a basis of only thirty years' life—as Mr. Munby proposes. Even so, and it is not admitted that there is the very least justification for such a radical departure from the recognised economic

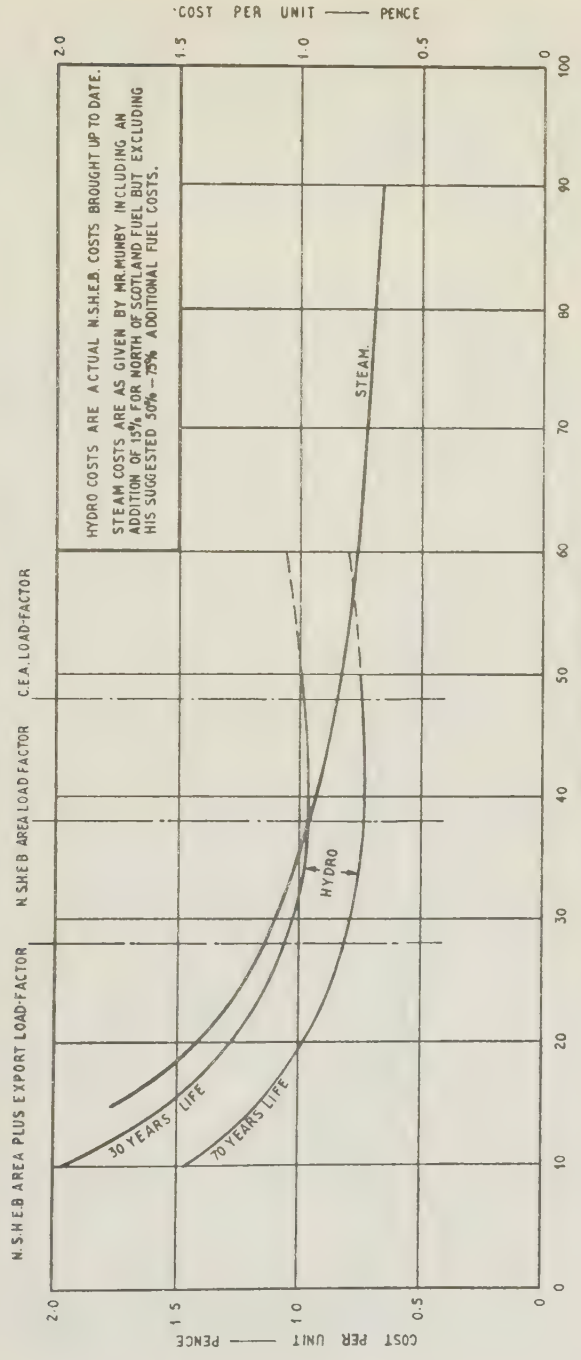
COST PER UNIT —— PENCE
HYDRO COSTS ARE ACTUAL N.S.H.E.B. COSTS BROUGHT UP TO DATE.
STEAM COSTS ARE AS GIVEN BY MR. MUNBY INCLUDING AN ADDITION OF 15% FOR NORTH OF SCOTLAND FUEL BUT EXCLUDING HIS SUGGESTED 50% – 75% ADDITIONAL FUEL COSTS.
STEAM
HYDRO
30 YEARS LIFE
70 YEARS LIFE
N.S.H.E.B AREA PLUS EXPORT LOAD-FACTOR
N.S.H.E.B AREA LOAD FACTOR
C.E.A. LOAD-FACTOR
ANNUAL LOAD-FACTOR PER CENT
COST PER UNIT —— PENCE

FIG. 1. Relative costs of hydro and coal-fired steam generation.

life for such works, hydro generation is still more favourable than steam. The interesting point is that after the hydro plant had been so written off the cost of production would be so low that no other means of generating electricity in thirty years' time could ever hope to compete with it. The question may then be asked, ' What is the justification, economically or otherwise, for making the present generation pay now for electricity so that succeeding generations may get it for next to nothing? '

Nuclear Electricity

A comparison of the costs of generation at hydro and at nuclear stations is shown on Fig. 2 and in Table II. The costs of generation at hydro-electric stations are those at a number of hydro-stations in the North of Scotland calculated on the basis of a seventy-year amortisation period. They fall within the band marked, and the mean curve has been drawn within this band. This mean curve has also been re-calculated on the basis of a thirty-year amortisation period and plotted on Fig. 2.

For the cost of generation from a nuclear station, a full line has been drawn on the same Figure. This is based on present-day estimates for the capital cost of nuclear plant together with the cost of nuclear fuel, and for the maintenance of the plant and other services. It is reasonable to suppose that the capital cost of nuclear plant will gradually be reduced over the coming years, although there does not at present appear to be any prospect of getting below approximately £100 per kW installed. It is also necessary to note that while the amortisation period for the conventional items in a nuclear station may be taken to be the same as that for a conventional thermal station, the reactor items, which form a considerable part of the total cost, cannot be expected to have a comparable life. A period of not more than fifteen years has been recommended by Jukes and other authorities. A further capital charge arises in connection with the purchase of nuclear fuel. The fuel replacement cost for a nuclear station is a substantial item. World prices for uranium may well harden if the demand for nuclear power builds up rapidly, and doubt exists about the credit that may reasonably be allowed for by-product plutonium production. Some designs of nuclear reactor would require the use of rare and expensive materials such as zirconium and beryllium for the fabrication of the fuel elements, and this may add appreciably to the fuel costs even if the cost of fissile material is reduced. If optimistic figures are taken, corresponding to a possible state of affairs in, say, ten years' time, it does not seem likely that the cost of nuclear power can be reduced below the lower dotted line shown in Fig. 2. On this

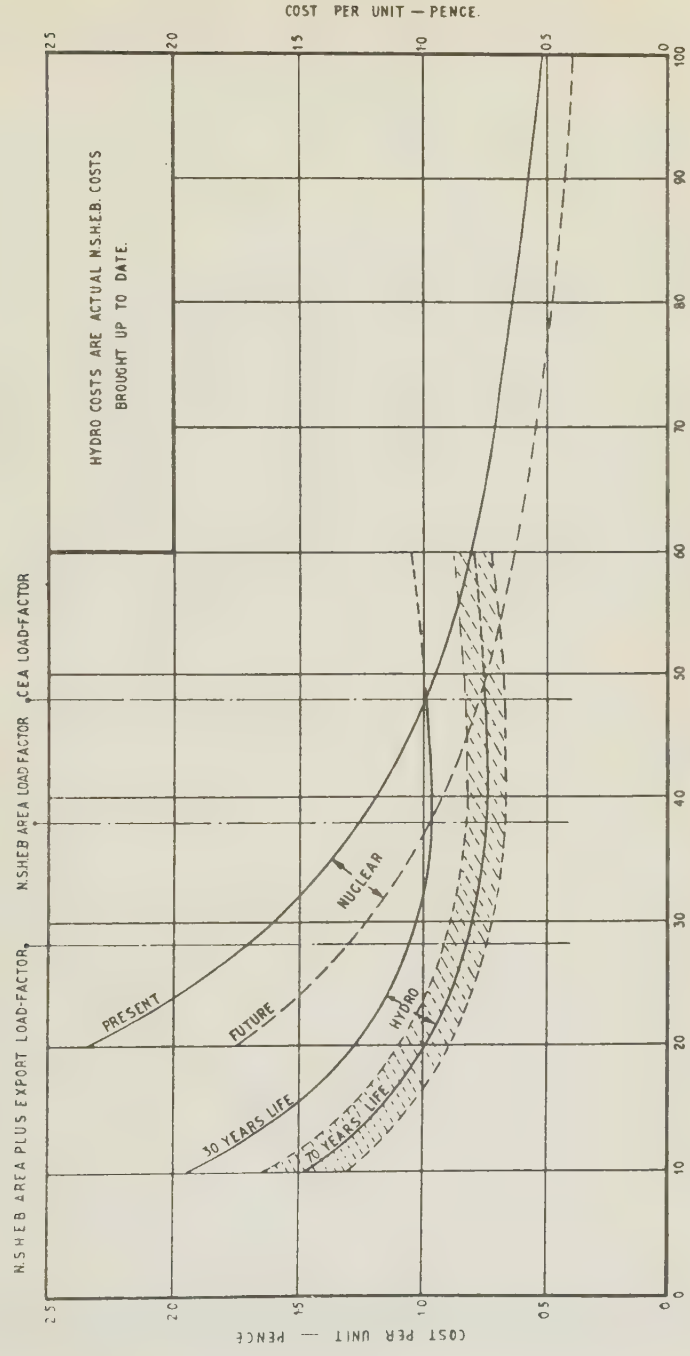

FIG. 2. Relative costs of hydro and nuclear generation.

assumption, and accepting the unrealistic period suggested by Mr. Munby of thirty years' amortisation for hydro stations, hydro power is likely to continue to be competitive at load-factors below about 40 per cent. with all forms of thermally-produced power.

Everybody will take advantage of atomic energy when it comes as a practical competitive proposition. 'Will it really be any cheaper than water power?' is the question. Nothing at this moment justifies the statement or even the assumption that in thirty years it will cost less than or supersede hydro power. Until then the Board certainly ought not to be asked to make present consumers bear an amortisation load which they should not be asked to carry. The Board's hydro schemes are sound, and so long as the costs of further developments fall within the zone of production cost given in Fig. 2, there is every reason why Parliament should allow, without any danger to the country's finances, the Hydro-Electric Board to continue to develop all the water power which the Highlands can reasonably produce. Hydro electricity cannot but stand unrivalled as a source of power because, without amortisation of its substantial initial expenditure, its cost is only about half that of electricity from coal, and when the initial expenditure has been amortised it will cost practically nothing.

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ELECTRICITY IN THE NORTH OF SCOTLAND: A REJOINDER

I AM grateful for the care which MacDonald and Kay (MK for short) have taken in reply to my article. But I am not sure that they have got to the heart of the matter.

1. My main point was whether it was economic to build further hydro-electric dams, except for peak-load supply. What prices are charged to consumers is a quite secondary matter; it is not obvious to an economist that the criteria to be used for deciding on production policy should form the basis of pricing policy. Whether money has been wasted in the past in building dams or not is also secondary; I did not raise this question. Nor is it a major matter whether Parliament or the Board are responsible for waste, if waste occurs. A good deal of MK's reply is thus not concerned with the main issue.

2. The nub of my argument was in Table VII (p. 35). Load factors are not ignored. MK's Figures and Tables for hydro costs coincide with mine for capital costs of £70 per 1,000 units per annum. There is no disagreement about the conclusions to be drawn, if the Board can keep capital costs down to this figure.

3. The crux of MK's reply is the *ex cathedra* assertion that the Board's schemes under construction 'will cost at present prices . . . £68 per 1,000 kilowatt-hours per annum which compares with an average of £61 for all the hydro schemes put into service since the war'. More space could have been given to explaining these figures. The Board had previously published only the figures given on my pages 25-6, which refer to estimated costs at various dates. The first published figures of *completed* costs were given by Mr. T. Johnston in October 1956, when he said that the final cost of the Garry scheme, as completed in 1956, was £61 per 1,000 units per annum. In March 1948 the estimated costs were £29, and work started in 1951; in terms of 1954-55 prices, it seems reasonable to assume that this means something over £70. What we need are detailed figures of the capital costs of particular schemes, present and future, in terms of stable pounds. Are we to believe that the Board did not start to develop the cheapest sites, and that it is not the case that later sites are likely to be more costly than earlier ones?

4. It is not at all clear how the Tables and Figures have been built up. They are described as 'the cost of all post-war schemes', and 'the mean curve drawn within the band of costs at a number of hydro-stations'; the curve looks remarkably like a median curve

and not a weighted average. We are referred to Hunter and Mountain's Fig. 3, which is described as a 'typical' curve, but a footnote had to be added that it referred in fact to one particular hydro site. Before we can rely on MK's generalisations, we must know more about these figures.

5. MK's argument about the average load-factor of the Board seems to be based on the fallacy of averages—that, to meet an average load-factor over a large area, every station has to have the same load-factor.

6. MK's nuclear costs, described as 'present-day' and 'future optimistic estimates' correspond in fact to the Atomic Energy Authority's 1955 estimates according to the different prices to be obtained from by-product plutonium. Since then, the experience of Calder Hall has shown that more heat can be produced per unit of capital than was expected.

7. MK's argument about the cost of electricity in the Board's area, if steam had been used, is vitiated by an error of fact and an error of logic. (i) They compare my C.E.A. figure of 0·80d. per unit *sold* with the Board's figure of 0·74d. per unit *generated*; the C.E.A. figure per unit generated is 0·73d. (ii) The Board's figure contains a large element of pre-war costs. Just under a quarter of the hydro output in 1955 was generated in pre-war stations at about 0·2d. per unit (see my footnote 8); costs at post-war hydro stations must have been about 0·73d. per unit to make up an average of 0·6d. for all hydro output, and MK's 0·66d. must be correspondingly raised. C.E.A. costs do not contain a similar amount of past costs at lower price-levels. MK ignore the fact that the pound sterling is not a stable unit, and for this and other reasons their conclusion on this point does not follow from their figures. In any case, this whole discussion of the past is a red herring: it is atomic energy that has revolutionised the situation.

8. Disquiet will be bound to remain about the Board's plans, so long as their spokesmen and defenders do not make public the really important information on which proper estimates could be based. Why this reluctance to give us the full figures of capital costs?

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THE LINEAR PROGRAMMING APPROACH TO PRODUCTION PLANNING

I

Introduction

During the last few years, considerable attention has been paid by American economists, both academic and industrial, to the development of a new technique of production planning, known as mathematical programming. More recently, interest has been shown in this country, and a number of firms have already applied it to some of their problems. Successful applications—mainly in the United States—include the allocation of scarce machines to their most profitable uses, determination of 'best' or minimum-cost blends, and the routing of transport.[1] In this article an attempt is made to illustrate some of the basic ideas, and to indicate potential applications of the technique. Discussion is confined to the special case of *linear* programming, since, so far, no general method of solving non-linear programming problems has been developed.

II

The Nature of Linear Programming

In its analysis of the individual firm, the starting-point of mathematical programming is the same as that of traditional economic theory.[2] The aim of production is to transform inputs into outputs in such a way as to maximise profits. The problem tackled by the programming approach arises when the supply of some inputs is limited and cannot be increased in the planning period being considered. If there is a choice of uses for these scarce inputs, and if profits vary according to the uses chosen, a programming problem exists: to determine the 'optimum allocation' of resources to production, 'optimum allocation' being defined as that which maximises the firm's profit in the planning period. The linear programming approach to this problem consists of two steps: (i) its formulation as a mathematical problem, and (ii) the solution of the mathematical problem. These are discussed in turn in the following paragraphs. Two simplifying assumptions will be made: that the firm can sell all that it can make of any product at current market prices, and that

[1] Cf. Henderson and Schlaifer, 'Mathematical Programming', *Harvard Business Review*, June 1954.

[2] For a full theoretical discussion see R. Dorfman, *Application of Linear Programming to the Theory of the Firm* (1951).

all except the scarce inputs are available in any desired quantities at current market prices.

A mathematical formulation of the allocation problem implies the use of a theory of production. In the literature, the appropriate programming theory is usually discussed under the name of activity analysis.[3] It is not proposed here to discuss the theory in detail, but it may be useful to indicate briefly how it differs from marginal analysis. Both linear programming and marginal analysis take as given the techniques by which inputs are transformed into outputs, and both assume constant returns to scale. They differ radically, however, in their conceptions of the nature of the techniques. The difference may be illustrated by considering the case of a two-factor, single-product firm. In marginal analysis, the relation between inputs and output is expressed in the form of a single-valued production function which shows the maximum output for any given set of inputs. Since this function is assumed to be continuous within limits set by the technology, it follows that if the quantity of one input to be used is fixed, output can still be increased or decreased by varying the quantity of the remaining input. The firm has therefore to choose the optimum from an infinite set of possible outputs. Linear programming takes the view that the technology does not allow such a choice, and that, in fact, if the quantity of one input to be used is fixed, then the quantities of the remaining input and of output are also determined. In other words, the ratios of inputs to other inputs, and of inputs to outputs, are fixed. Hence a limited supply of one input would provide an effective upper boundary to output, and the only possible variation would be in scale. Given sufficient demand for the product, therefore, output will be completely determined by the available supply of the limited input. Let us suppose, however, that the technology provides not one, but two ways of making the same product (or two different products), the two ways being distinguished by two sets of inflexible input-output ratios, *i.e.* some possibility of factor substitution exists, though not of continuous substitution as in marginal analysis. In this case variations in output become possible since the scarce input can be allocated to the two methods of production in different quantities, and the methods can be used at different levels of production provided they can be carried on independently. In programming terminology, the two methods are referred to as activities or processes,[4] and the

[3] Cf. *Activity Analysis of Production and Allocation*, edited by T. C. Koopmans (1951).

[4] Koopmans, *op. cit.*, uses the term 'activity' in his general theory of production; Dorfman, *op. cit.*, uses 'process' in the particular context of the firm.

firm's production problem is to allocate the scarce input to them. Evidently, by postulating a sufficiently large number of such activities, it would be possible to approximate the production function of marginal analysis. It is of the essence of linear programming, however, that there is a *finite* number of activities or processes available to the firm.

This concept of production as a set of activities can be extended to cover many types of product, each with one or more methods of production, provided that the total number of methods is finite. The basic problem still remains that of selecting which activities are to be carried on, and at what levels, so as to maximise profits within limits set by the availability of some inputs. Furthermore, although it may seem that the finite set of activities is merely a modification of the conventional production function, it has two novel features of great value in application. The first arises from a difference in the treatment of inputs of which there is a limited supply. The programming approach, in distinguishing between absolute limitation in supply and relative scarcity in production, recognises explicitly that when the available supply of several inputs is fixed, the technological relations between them may be such that the optimum allocation leaves idle some of one or more of the inputs. To every fixed factor or limited input corresponds what is called a 'disposal activity',[5] which adds to the set of activities the alternative (with no revenue and no variable cost) of not using that input. The second feature arises from the nature of the difference in concepts, and may be illustrated with reference to the two-factor, single-product case. In this case, if *both* factors were fixed, output would be fully determined by the production function, given sufficient demand. The production plan would use a single combination of inputs and outputs. It fails to consider the possibility of using *several distinct combinations at the same time.* In programming this is an inherent consideration since the problem is essentially to determine which activities (fixed combinations) to use and on what scale. In effect, in using the production function, which is a single expression for an infinite set of activities, marginal analysis attempts to find a single, optimum activity. Programming, in dealing with a finite set of activities, takes into consideration the consequences of using two or more activities at the same time.

The linear programming view of production does not permit the use of differential calculus in solving the production problem. A further assumption, however, facilitates a mathematical formulation

[5] Or, of course, (Dorfman) 'disposal process'. Some writers use the term 'slack variable', *e.g.* Charnes, Cooper and Henderson, *An Introduction to Linear Programming* (1952).

which can be solved. It is assumed that if several activities are used simultaneously, the total of any input used is the sum of the individual inputs, and the total of any output is the sum of the individual outputs. The activities can take place independently: they are interdependent only to the extent that they require the same factors of production, but in different proportions. Now, if the unit level at which an activity takes place is defined as that which produces a unit output, the amounts of different inputs required at this level (the input-output ratios or technical coefficients) are known. In any production plan, the total input of a factor F required for a given activity is the product of the number of units to be produced and the appropriate technical coefficient. If the supply of F is limited, and the complete set of activities is given, the assumption simply means that the sum of these products over all activities must be less than,[6] or equal to, the quantity of F available in the planning period. There are similar conditions for other inputs whose available supply is limited. These conditions, which take the form of linear inequalities (*e.g.* $K_1q_1+K_2q_2+ \ldots K_nq_n \leqq F$ where the K's are the technical coefficients and the q's the levels of each activity), together place an effective boundary on the firm's production opportunities. If the net contribution to profits plus fixed costs[7] per unit of activity is defined as the difference between the selling price of the product and the cost of the variable inputs used in it, then profits will be maximised by maximising the total net contribution, which is the sum of the net contributions of the individual activities, and will have the linear form $C_1q_1+C_2q_2+ \ldots C_nq_n=R$. Hence the production problem is to find the levels at which to carry on different activities so that R is a maximum and the boundary conditions are not violated. Mathematically the problem is to find a set of positive or zero values of the variables $q_1 - - - q_n$ which maximises the linear function R subject to a set of linear inequalities. In Section III it will be seen that this formulation follows naturally from a typical, though highly simplified, statement of a firm's problem.

The basic assumptions of linear programming can now be summarised:

(*a*) technology consists of a finite set of activities characterised by fixed input-output ratios;

(*b*) these ratios are independent of the scale of operation of the activities;

(*c*) the activities are independent of each other, so that the sum

[6] The 'less than' allows for leaving some F unused, *i.e.* it represents the 'disposal activity' for factor F.

[7] Fixed costs are here taken to include the costs associated with the limiting factors, *e.g.* the costs of owning or hiring plant, depreciation.

of individual inputs gives total input, and the sum of individual outputs gives total output ; and

(*d*) any positive level of any activity is possible, provided a sufficient quantity of the necessary inputs is available.

These assumptions are not quite as restrictive as they may seem at first sight. The second assumption, for instance, implies that a unit of input of labour combined with the other factors will always yield the same return. This would not be true if labour were scarce and some hours of labour (*e.g.* overtime) cost more than others. Such a situation could be dealt with in programming by the simple device of defining labour at ordinary rates as a different input from labour at overtime rates.[8] Any activity using labour would then be divided into two activities, one using ordinary labour and the other using overtime labour ; otherwise inputs and outputs remain the same. The net contribution of the latter would be smaller than that of the former ; hence overtime labour would not be used unless the available supply of ordinary labour was fully employed. A similar device could be used to deal with situations in which price falls in discrete steps after a given quantity is sold. Thus the second assumption is very restrictive only if supply and selling prices vary continuously with quantities. The divisibility assumption (*d*) is of no great practical importance except where the products are large and discrete, such as ships or aeroplanes. The third assumption, that of ' additivity ', may sometimes be questionable on technical grounds, *e.g.* in blending problems where some chemical action may take place in the blending process. In general, however, it will be valid. The first assumption, that of the finiteness of the set of activities, is rather different in nature from the others. It may be true of some industries, *e.g.* light engineering, but not true of others, *e.g.* some types of chemicals. To the extent that entrepreneurs tend to think in terms of discrete quantities (*e.g.* an extra ton or hundredweight of fertiliser) rather than in terms of continuous substitution, when considering the application of factors to production, the finiteness assumption is not unduly restrictive even when it is not strictly valid.

The most generally useful procedure for solving problems of the above type is known as the Simplex Method. Proof of the validity of this method requires some knowledge of mathematics,[9] but the basic principle underlying it can be stated fairly briefly. The mathematical analysis shows that if there are, say, n conditions, then,

[8] Cf. Dorfman, *op. cit.*, p. 16.

[9] Cf. Koopmans (ed.) *op. cit.*, p. 339 (G. B. Dantzig, ' Maximisation of a Linear Function of Variables subject to Linear Inequalities '), and Charnes, Cooper and Henderson, *op. cit.*, Pt. II.

provided a feasible solution exists, there is always at least one optimum solution in which the number of activities used does not exceed *n*. Given this, the Simplex Method consists of finding a feasible solution in which *n* activities are used at positive levels, and moving from this starting point to new *n*-activity solutions, by the substitution and removal of activities, until it is found that no further substitution can increase profit. The final solution gives the optimum allocation of resources. An attempt is made in the next Section to illustrate the logic of the Simplex Method. There are other methods of solving linear programming problems, but the most useful of these, *e.g.* the so-called transportation-problem method, can be used only in special circumstances.

III

A Simplified Example

In this Section the formulation and solution of a very simple example is given. Restrictions on production are assumed to be attributable only to the limited availability of plant. The programming approach, however, does recognise that in any planning period production decisions may also be affected by other elements, *e.g.* the supply of raw materials, sales commitments, and questions of general policy. For the latter, linear programming can provide relevant information ; the former can be incorporated in the statement of the problem—raw materials as an extra input restriction and sales as an output restriction.

Consider the following problem. An engineering works is organised in two divisions, X and Y, in each of which the machine capacity available during the next month is 1,000 hours. The firm can make three different products, A, B, and C, and can sell all that it can make in a competitive market at a unit price of £1. The machine-time required per unit is different in each case, being as follows:

Machine-time per unit in hours

Division	*Product* A	*Product* B	*Product* C
X	·20	·40	·30
Y	·40	·20	·30

Total variable cost[10] is £·445 per unit for A, £·455 for B, and £·455 for C. How should the firm use its available capacity so as to minimise profit? A programming problem is involved here since the firm has

[10] The accounting problem of defining and measuring variable cost is by-passed here. It is known, however, that programming may involve a re-appraisal of accepted accounting conventions.

a *choice* of courses of action: to produce only A, only B, only C, or some combination of A, B, and C. Fixed costs, by definition, are not affected by the proportions in which A, B, and C are selected for production; hence they may be omitted from the calculations. It is sufficient to consider only the total net contribution of alternative programmes to fixed costs plus profits, the net contribution being defined as the difference between revenue from sales and variable costs. Assuming constant returns to scale, it follows that net contribution per unit product is the difference between selling price per unit and variable costs per unit. Hence we have:

net contribution of product A per unit sold at £1 = £·555
„ „ „ product B „ „ „ „ £1 = £·545
„ „ „ product C „ „ „ „ £1 = £·545

The problem can now be set up in linear programming form in either of two ways, of which the first arises directly from the criterion of maximising profit while the second, known as the 'dual' method, is closely related to the economic concept of 'opportunity cost'. The results are obtained in two parts, one showing the optimum output of A, B, and C, and the other showing the unit values of factors (divisions) to the firm and the profits foregone by any different allocation of factors. This second set of results, known as the 'dual' solution, is as important from the point of view of optimum allocation as the first, and is probably the more useful result of linear programming from the policy-making point of view. Mathematically, either method will produce *both* sets of results on solution.

Method I—the linear programming problem

Let q_A, q_B, and q_C be the number of units respectively of A, B, and C to be produced. The total net contribution of production to fixed costs plus profits will then be:

$$P = £\cdot 555q_A + £\cdot 545q_B + £\cdot 545q_C \quad \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

It is required to make this total as large as possible. The quantities that can be produced, however, are limited by available capacity; that is, the total time that can be used in Division X, for instance, must not be greater than 1,000 hours. Since product A requires ·20 hours of X, product B, ·40 hours, and product C, ·30 hours, the sum $\cdot 20q_A + \cdot 40q_B + \cdot 30q_C$ must be less than or equal to 1,000. A similar restriction holds for Division Y. Hence we have:

for X: $\cdot 20q_A + \cdot 40q_B + \cdot 30q_C \leqq 1{,}000$
for Y: $\cdot 40q_A + \cdot 20q_B + \cdot 30q_C \leqq 1{,}000$

The optimum programme may, of course, be one which leaves some machine capacity idle. If q_X and q_Y are the numbers of hours

of unused capacity in Divisions X and Y, then the above inequalities may be rewritten:

$$\text{for X: } \cdot 20q_A + \cdot 40q_B + \cdot 30q_C + q_X = 1{,}000 \quad \ldots\ldots\ldots\ldots \quad (2)$$

$$\text{for Y: } \cdot 40q_A + \cdot 20q_B + \cdot 30q_C + q_Y = 1{,}000 \quad \ldots\ldots\ldots\ldots \quad (3)$$

Provided that no extra cost is attached to leaving some capacity idle, the problem, stated mathematically, is:

to find q_A, q_B, q_C, q_X, q_Y—all greater than or equal to zero[11]—such that

$$P = £\cdot 555q_A + £\cdot 545q_B + £\cdot 545q_C$$

is a maximum, subject to the fulfilment of conditions (2) and (3). It should be noted that the sequence in which A, B, and C are scheduled through Divisions X and Y is not taken into account. This is an independent but closely related problem.

Method II—the dual problem

From the economist's point of view the alternative method of setting up the manufacturer's problem is possibly more interesting since it makes use of the concept of 'opportunity cost'. The firm merely attempts to answer a question phrased in some such manner as the following:

> What will be the minimum cost (in terms of profit foregone) of leaving available capacity idle?
>
> *or*
>
> Given that the firm has a choice of more or less profitable uses for its capacity, what is the minimum (sub-contracting) price that it should require from another firm wishing to make use of all its available capacity for a month?

Clearly the answer to those questions will be dependent on the revenue obtainable from the alternative uses at current market prices. This is the starting-point for the second method of formulating the problem. The data, of course, are the same. Let p_X and p_Y be the cost of leaving idle one unit (or hour) of X, Y. The total cost of not using the plant is then:

$$C = £(1{,}000p_X + 1{,}000p_Y) \quad \ldots\ldots\ldots\ldots \quad \text{(i)}$$

Now consider the alternative uses.

To produce A, the firm requires ·20 hours of capacity in X, and ·40 in Y. The minimum cost to the firm of leaving this capacity idle is $£(\cdot 20p_X + \cdot 40p_Y)$. If A is the *best* alternative use, this sum is equal to the net contribution from one unit of A: if A is not the best alternative use, this will be greater than the net contribution from

[11] This is, of course, a necessary condition since negative quantities cannot be produced!

one unit of A. Hence, we may write down as a condition to be satisfied by the optimum values of the p's:

$$\cdot 20p_X + \cdot 40p_Y \geqq \cdot 555$$

Similar conditions may be written down for products B and C:

$$\cdot 40p_X + \cdot 20p_Y \geqq \cdot 545$$

$$\cdot 30p_X + \cdot 30p_Y \geqq \cdot 545$$

Now, if A is *not* the best alternative use, allocation of this capacity to make product A leads to a loss of potential profit (or opportunity cost) of, say, p_A, which will be the difference between the minimum value of the capacity required to make a unit of A and the net contribution per unit of A. Hence we may rewrite the condition for A thus:

$$\cdot 20p_X + \cdot 40p_Y - p_A = \cdot 555 \quad \text{..... (ii)}$$

For B and C, we have:

$$\cdot 40p_X + \cdot 20p_Y - p_B = \cdot 545 \quad \text{..... (iii)}$$

$$\cdot 30p_X + \cdot 30p_Y - p_C = \cdot 545 \quad \text{..... (iv)}$$

The problem is therefore to find p_X, p_Y, p_A, p_B, p_C—all greater than or equal to zero—such that

$$C = £(1{,}000p_X + 1{,}000p_Y)$$

is a minimum, subject to the fulfilment of the conditions (ii), (iii) and (iv).

The logic of the programming solution

A rigorous proof of the Simplex Method, as already stated, requires some fairly advanced mathematics.[12] The logic of the method, however, is basically the same as the logic of any production planner. Let us consider briefly how the latter might approach the problem outlined on pp. 34-5. To begin with, product A is more profitable per unit than B or C. Output of A is limited by the fact that production of one unit of A requires ·40 hours of Division Y's time, and only 1,000 hours are available. If the maximum amount of A is made ($\frac{1{,}000}{\cdot 40} = 2{,}500$ units), the total net contribution will be 2,500×£·555, or £1,387·5, Division Y's capacity will all be taken up, and Division X will be idle for half the time, since A takes only half the time in X that it takes in Y. Next consider whether this programme can be bettered. Alternative programmes must include B and/or C, whose net contributions per unit of output are equal. If the firm makes one unit less of product A, ·40 hours capacity of Y (plus ·20 of X) will become available. This can be used, in conjunction with some of the idle X capacity, to make two units of B, which takes only ·20 hours

[12] Cf. footnote 9. A simplified outline of the algebra is given by K. S. Lomax, 'Allocation and Programming in Modern Economics', *The Manchester School*, September 1953.

of Y, or one and a third units of C, which takes ·30 hours of Y. There will be a *loss* of one net contribution from the reduction in A (£·555), but a *gain* of either two net contributions from the production of B (£2 × ·545), or of one and a third net contributions from the production of C (£1⅓ × ·545), for every unit of A whose capacity can be so reallocated. Clearly B is the better choice. A few simple calculations show that it is possible to make 1,666·6 units of A and 1,666·6 units of B with the available capacity, thereby raising the total net contribution to £1,833·3. The next step is to consider whether *this* programme can be bettered. Examination of the original machine-times shows that if the output of A is reduced by a half-unit, and of B by a half-unit, enough capacity in X and Y will be released to make a unit of C. The result will be a *loss* of £(½ × ·555 + ½ × ·545), and a *gain* of £(1 × ·545) from production of C, *i.e.* there will be a *net loss* of £·005. Production of C will therefore lead to a loss of potential profit. The last programme may therefore be accepted as the most profitable.

This rather loose but relatively simple argument is probably sufficient to illustrate the kind of logical considerations that the industrial planner must have in mind when deciding how to allocate his resources. Realistic cases, however, will very rarely be as simple as this. The number of alternative methods of combining scarce resources to make saleable products may run into scores, or even hundreds, as may the number of categories of scarce resources: and policy restrictions and sales commitments may still further complicate the problem of choosing the optimum production plan. In most cases, in fact, the *scale* of the problem will be such that the mental and clerical capacity of the planner is too limited to permit a full application of the logical approach used in the simple case, and he is forced to guess—possibly to make a very good guess—the optimum plan. The purpose of the linear programming formulation of the problem is to eliminate such guess-work, and to facilitate a *systematic* application of the approach outlined above. The Simplex Method, in fact, is merely a reduction of the argument to a mechanical routine:[13] select a feasible programme and calculate the net loss or gain from any alternative use (activity) not in the programme; incorporate the activity giving the greatest net gain into the programme to the maximum amount and repeat the procedure for the new programme; when no alternative use produces a net gain, the optimum programme has been found. The additional feature of the Simplex Method is that it makes use of an important mathematical proposition:[14] *in any linear program-*

[13] For detailed instructions on the Simplex routine, see Charnes, Cooper and Henderson, *op. cit.*, Pt. I.

[14] Koopmans, *op. cit.*, p. 341, theorems A and B.

ming problem for which a feasible solution exists, there is always at least one 'optimum' solution in which the number of activities used does not exceed the number of restrictions. This enables the Simplex Method to concentrate on finding the optimum from a limited class of possible solutions; while the *net gain* criterion ensures that, once a programme from this class has been chosen, all less profitable programmes from it are excluded from further consideration. Thus fairly large problems are reduced to a size amenable to modern computing techniques. In using the Simplex Method, high-speed electronic computing methods are preferable, but known applications, involving between twenty and thirty alternatives and fifteen to twenty restrictions,[15] have been solved reasonably quickly using ordinary desk-machines.

The full solution to the simple problem given above is shown below. The discrepancy between the total net contribution (£1,833·3) and the total value of capacity (£1,834·0) is caused by 'rounding'.

(*a*) *Optimum programme*

Units of A: 1,666·6

Units of B: 1,666·6

Total net contribution: £1,833·3

(*b*) *Marginal value of capacity*

Division X: £·892 per hour

Division Y: £·942 per hour

Total value of capacity: £(1,000 × (·892 + ·942)) = £1,834·0

(*c*) *Cost of alternative allocation of capacity* (opportunity cost)

Per unit of C: £·005.

Information provided by the Simplex solution, but not shown here, includes the most efficient methods of adjusting the programme if, for some reason, an alternative allocation of resources is preferred, or if the amount of capacity available should change. Some potential applications of these results are discussed later.

IV

Applications

Although much of the stimulus in programming research originated in the investigation of logistic problems for the U.S. forces, a number of private firms have successfully applied the technique to commercial operations. An example has been quoted of a firm which made savings of the order of £100,000 a year on transport costs by carrying out a 'small Linear Programming operation'.[16] Some of the industrial

[15] N. Williams, 'An Application of Linear Programming to the Selection of Raw Materials', *Applied Statistics*, March 1955.

[16] Ferranti Ltd., *Conference on Linear Programming* (1954) (Duplicated record of Conference Proceedings), p. 91.

problems to which the methods have been applied are described briefly in the following paragraphs.

One of the earliest applications was to the problem of gasoline blending.[17] In its simplest form this problem can be stated as follows: the products of an oil refinery are usually required to satisfy certain quality specifications—for instance with respect to ignition properties and volatility—which determine the grade, and hence the price at which they are sold. These products are made by blending different crude oils, and, possibly, introducing other chemicals in the process, in such a way that the final products possess the desired properties. An important feature is that the properties of the product can be expressed as (linear) combinations[18] of the corresponding properties—measured in terms of, *e.g.*, octane rating and vapour pressure—of the components. Since the capacity of a refinery and the supplies of crude oil in any period are limited, a choice has to be made of which products to make, in what quantities, and, where more than one method of refining is available, how to make them. Given the properties of the crude oils, this can be set up as a linear programming problem, the objective of which is to maximise a (profit) function of the volume of products made and the quantity of ingredients used, subject to the limitations imposed by the capacity of the refinery, the supplies and characteristics of the crude oils, and the quality requirements of the products. Blending, of course, though important, is only one phase of refinery operations. Programming techniques have been extended to other phases, such as the determination of optimum production rates and stock levels to meet seasonal requirements, the allocation of available crude oils to different refineries, and the planning of refinery improvements.[19]

A somewhat similar application is the 'nutrition' problem, an important industrial example of which is the manufacture of cattle food.[20] In this case the linear programming problem arises from the need to combine various ingredients into a cattle food possessing

[17] A. Charnes, W. W. Cooper, and B. Mellon. 'Blending Aviation Gasolines', *Econometrica*, April 1952.

[18] Doubts as to the validity of the linearity assumption in this context have led to research on non-linear programming, cf. A. S. Manne, 'Concave Programming for Gasoline Blends', *Report* p—383 (The Rand Corporation, Santa Monica, California).

[19] G. H. Symonds, *Linear Programming: The Solution of Refinery Problems* (Esso Standard Oil Company, New York, 1955).

[20] F. V. Waugh, 'The Minimum-Cost Dairy Feed', *Journal of Farm Economics*, August 1951: H. C. Mackenzie, and T. E. Godsell, 'Linear Programming and the Cost of Pig-Fattening Rations', *Journal of Agricultural Economics*, January 1956. An early study of the 'nutrition' problem was by G. J. Stigler, 'The Cost of Subsistence', *Journal of Farm Economics*, May 1945.

specified nutrient values. Thus feeding requirements may call for rations of a given weight with specific protein, starch equivalent, fibre and oil content. To make the required ration, a number of grains or other ingredients, such as fish-meal, are available at known prices. The nutrient values of each ingredient are also known ; some are rich in proteins, deficient in starch, or too oily ; others possess different, possibly complementary, properties. Linear programming is used systematically to determine which combination of ingredients will provide a given quantity of a specified mixture at minimum cost.

Another general type of problem in which programming has been found useful is the planning of machine or department loads. Here the approach is merely a more realistic version of that described in the simple example used in Section III. The problem arises where a number of different machines or departments are involved in the manufacture of various products ; the interdependence of the individual sectors of the plant usually makes it impossible, in a given period, to increase the output of one product without adjusting loads and outputs throughout. Linear programming provides a means of planning work-schedules in such a way that the maximum benefit is obtained from available equipment and labour. One example[21] of this type of application shows how output was increased, and bottleneck problems in screw-machine and grinder departments considerably eased, by the introduction of linear programming. It should be emphasised, however, that programming can solve only the quantitative aspects of production-scheduling problems ; it can be used to set objectives, but it does not eliminate difficulties caused by the need for a fixed sequence of operations. And it can deal only indirectly with the problem of planning the most efficient schedules when different machine set-up times are required for the various products, unless set-up is small compared with running time.

Perhaps the best-known application of linear programming is to the so-called ' transportation '[22] or distribution type of problem. A classical example of this is the routing of empty ships. A given number of ships—oil tankers, say—at present in ballast at several different ports, are to be directed to certain other ports to pick up cargoes. The

[21] A. Charnes, W. W. Cooper, and D. Farr, ' Linear programming and profit preference scheduling for a manufacturing firm '. *Journal of the Operations Research Society of America*, Vol. I, May 1953. See also M. E. Salveson, ' On a Quantitative Method in Production Planning and Scheduling ', *Econometrica*, October 1952.

[22] T. C. Koopmans, ' Optimum Utilization of the Transportation System ', *Econometrica*, Vol. 17 (Supplement), July 1949. The ' transportation ' problem is a special type of linear programming for which an easier method of calculation than the Simplex is available. See also A. Land, 'A problem in transportation ', in Ferranti Ltd., *Conference on Linear Programming* (1954).

cost of transferring them from the ports of origin to the destinations can be measured in terms of days at sea, and this is known for the route between each origin and each destination. The programming problem is to route the ships so as to minimise the total number of days at sea, subject to the restrictions that no port of origin can despatch more ships than are available and that each destination should receive the number of ships required. The number of ships available must, of course, equal or exceed the number required! If one substitutes, for ports of origin and destination, factories and warehouses, or similar links in the chain of distribution, it is fairly easy to visualise potential applications. Several cases of routing schedules planned in this way are quoted in the literature. In the United States, for instance, the Heinz Company is reported[23] to have secured numerous advantages —a saving of senior executives' time, a reduction in freight costs, shortening of the planning period, elimination of the risk of back-hauling—by programming the supply of ketchup from its various plants to the regional warehouses. An extension of the technique enabled the same company, in a case where plant capacity exceeded warehouse requirements, not only to decide from which factories to supply the warehouses but also how much to produce at each factory.[24]

Numerous other examples can be quoted of the practical application of linear programming techniques: examples include the disposal of scrap metal,[25] the evaluation of tenders for contracts,[26] the efficient use of tanker fleets,[27] the procurement of aircraft engines for an air force base,[28] and the choice of crop-rotation plans.[29] How successful these applications have been it is difficult to assess, but there is little doubt that they have proved linear programming to be, potentially at least, a very powerful new tool for management. Some of the ways in which it can help planning and decision-making are discussed in Section V.

[23] A. Henderson and R. Schlaifer, *op. cit.*, pp. 76-8.
[24] *Idem.*, pp. 78-80.
[25] E. Kav and G. Morton, 'Linear Programming—an application to swarf recovery', *Metalworking Production*, 30th December 1955.
[26] E. D. Stanley, D. P. Honig and L. Gainen, 'Linear Programming in Bid Evaluation', *Naval Research Logistics Quarterly*, March 1954.
[27] G. B. Dantzig and D. R. Fulkerson, 'Minimizing the Number of Tankers to Meet a Fixed Schedule', *Naval Research Logistics Quarterly*, June 1954.
[28] A. J. Hoffman and G. L. Voegeli, 'Linear Programming', *Research Reviews* (Office of Naval Research, Washington D.C., August 1955).
[29] C. Hildreth and S. Reiter, 'On the Choice of a Crop Rotation Plan', Ch. XI in Koopmans (ed.) *op. cit.*; and B. Bowlen and E. O. Heady, 'Optimum Combinations of Competitive Crops at Particular Locations', *Research Bulletin 426*, Agricultural Experiment Station, Iowa State College, April 1955.

V

Some Uses of Programming Information

The information provided by linear programming and the Simplex Method has a number of important economic applications.[30] Some of these are dependent on the particular problem under consideration. For instance, in finding minimum-cost blends, the programming calculations provide a means of comparing the cost of different qualities of blend, *e.g.* in composing livestock rations, the cost of a 12 per cent. protein/60 per cent. starch-equivalent blend compared with a 15 per cent. protein/70 per cent. starch-equivalent blend. Other applications, however, are of more general interest from the economic and planning points of view. A few of these are outlined below.

1. *Alternative programmes.* Sometimes important conditions of production cannot be incorporated in the linear programming formulation. In such cases it is possible that the optimum programme shown by the Simplex solution cannot be adopted. Where a fixed sequence of operations is needed in production, for instance, the quantities and processing-times specified by the linear programming solution may not be compatible with the required sequences. It is then useful to refer to the Simplex calculations, which will show alternative optimum programmes (if any), second-best programmes, third-best and so on, until the best available programme is found. Where production engineers have to spend considerable time in working out feasible plans this may lead not only to a considerable saving of their time, but also to the selection of better plans than might otherwise have been chosen.

2. *Investment and the valuation of assets.* It has already been shown that the 'dual' of the optimum programme gives the marginal value of a unit of time on scarce capacity. The solution also states the range of capacity over which the value applies. This is clearly of importance in determining investment policy. When a new machine is bought, its capacity is normally available for all the hours in a given planning period, not just for one. Hence, in making investment decisions, it is useful to know both the marginal value and its range of application.

3. *Alterations in the planning framework.* In the short run there are two types of change of frequent occurrence which may have important repercussions on production plans. First, there may be changes in price: the supply prices of raw materials and labour, for example, are not fixed, and the selling price of products may change. Secondly, available capacity may be affected by the breakdown of

[30] Cf. Henderson and Schlaifer, *op. cit.*, Koopmans, *op. cit.*, pp. 31-2, etc.

machines or by the necessity of running-off an urgent order, while other conditions, such as the supply of raw materials and the size of guaranteed orders, may vary from period to period without any accompanying change in price. Changes of these kinds can easily be incorporated into the Simplex calculations already carried out, and the necessary adjustments to the programme can usually be calculated very quickly. An informed decision can thus be made almost immediately as to whether it is worth while making these adjustments or not, taking into account any other factors involved, *e.g.* the time needed for machine-setting, the state of inventories.

4. *Decentralisation of decisions.* This application, first mentioned by Koopmans,[31] has been much discussed. An illustration will show best how linear programming calculations could be applied in this sphere. Suppose that, in the example given in Section II, the firm is fairly large, with, say, three sales branches at scattered points. The central organisation, if it could sell all that it could make and adopted the optimum plan, would instruct the branches to accept orders only for products A and B. Let us suppose that the firm decides to produce some of product C, and allocates a maximum of fifty per period to each of its branches, thus accepting a loss of £(150 × ·005) in order to keep in the market for this product. If a sudden opportunity arises to sell more of C, and the customer is willing to pay a higher price, the branch concerned might have to refer to the head office and, in so doing, lose the opportunity. The contribution of linear programming to this situation is that, in addition to other instructions, the branches would also be provided with a set of 'opportunity cost' prices for each of the non-optimum products: in the case of C, £·005—the loss incurred if one unit of C is produced at current prices. Then, if an opportunity arose to sell more of C, the branch would be able to accept or reject the offer according as the price offered was higher than the old price by more than or less than £·005 per unit. Such a procedure, it is suggested, would accomplish three things:

(i) it would relieve higher management of many day-to-day decisions and leave it to concentrate on policy;

(ii) it would further the aim of profit maximisation by enabling the firm to take advantage of unexpected opportunities more quickly; and

(iii) it would increase the freedom of action of branch managers and give them more responsibility, without reducing central control over the general aims of the firm as a whole.

[31] Koopmans, *op. cit.*, pp. 93-5, and Charnes, etc., *op. cit.*, Pt. I. Koopmans' discussion is on a highly generalised level.

This outline tends to conceal two important aspects of the decentralisation procedure. Since the sets of prices to be given to managers are marginal prices, the instructions ought at least to specify the range over which these prices apply. There is also an implicit assumption that the flow of price information between the various branches and the centre is fairly rapid ; otherwise managers may accept orders on the basis of price information which is already out of date.

VI

Conclusion

The aim of this article has been to provide a brief outline of the nature of linear programming and some of its realised and potential applications. Full exploitation of the technique, particularly of the calculation, is greatly facilitated by a knowledge of the theory and application of matrix algebra, but it is quite possible to gain a thorough understanding of the principles involved, and also the ability to use the method, without such knowledge. All that linear programming does is to provide the production or business planner with a method of doing systematically and, in general, more efficiently, what he usually has to do by rule of thumb. It enables him, having stated the objective of his productive activity, to select the most economic way of achieving that objective. In the economic sphere, it provides the economist with an approach to the theory of the firm, which is fairly easily applied to production problems and which takes into account, as a fundamental part of its outlook, the relative inflexibility of modern industrial technology.

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THE REVISION OF THE JUTE WAGES-STRUCTURE [1]

THE rapid pace of economic change over the last ten or fifteen years has presented British industrialists with many new and complex problems. Changes in the average level of employment, in productive and marketing techniques, in industrial structures, and in the competitive position of individual firms and industries have all called for far-reaching changes in managerial policies and practices. One result of this complex of changes is that in a number of cases industrial wages-structures, which were appropriate to the conditions of the 1920s and 1930s, have become weighed down by a growing mass of anomalies, and so have come to act as a brake on the progress of the industries burdened with them. In consequence, a number of industries [2] are at present engaged in the preparation and introduction of new wages-structures designed to take account of contemporary economic realities, to improve labour relations, and to eliminate the adverse effects which an out-of-date wages-structure tends to exert on labour productivity.

I

THE INDUSTRIAL BACKGROUND

Up to the present time only one British industry—jute—has made extensive progress with the introduction, on an industry-wide basis, of a new uniform wages-structure. Jute is a relatively small manufacturing trade, with a total employment of some 20,000, which exhibits a remarkably high degree of localisation, some 95 per cent. of the total labour force being concentrated in the city of Dundee and an area of some fifteen miles around it.

The spinning and weaving of jute was introduced into Dundee in the second quarter of the nineteenth century as a substitute for the flax, flax tow and hemp then used by Dundee manufacturers in the production of a textile for bagging, packaging and other purposes

[1] A revised version of a paper read to the Economics Section of the British Association at its Bristol meeting in September 1955.

[2] The main industries so engaged are the boot and shoe, building, cotton, coal, and railway industries. Except in the case of the first of these, however, only limited progress has been made so far.

for which a coarse, cheap cloth was required. Used initially only as an adulterant with the dearer and more reputable hemp and flax, jute in time came to be worked on its own, and its cheapness won it a growing share of the expanding world market for packaging cloths. In the third quarter of the century the Dundee industry extended rapidly, a development accentuated by the heavy demand for jute products which arose from the wars of the period, but soundly based on the continuing expansion of the volume of international trade. At this time the Dundee manufacturers enjoyed a virtual world monopoly of the processing of jute, and by 1871 some 29,500 people in Dundee (over 47 per cent. of the occupied population of the city) were engaged in the manufacture of yarns and fabrics made wholly or partly of jute. Profits were generally good, and the wages paid, nearly all piece rates, compared not unfavourably with the levels then ruling in the older textile centres south of the Border. But this prosperity, which probably reached its peak in the early 1870s, was not destined to endure. Already by that date infant jute industries had been established behind tariff walls in a number of Continental countries, and, more important, the large-scale manufacture of jute goods on modern plant had begun in India. Thus, in the 1880s and 1890s, the Dundee manufacturers, increasingly shut out from their established Continental markets, were simultaneously losing their extensive export outlets in Asia, Australia, and along the western sea-board of the American continent, to the new Calcutta industry. In the present century, the pressure of competition from producers with more modern plant and a lower level of wage costs became increasingly severe. The British industry began to contract ; new investment declined ; and the level of wages in and around Dundee, an area which had become almost totally dependent on jute and its subsidiary trades for industrial employment, was forced down.

The employment position, and with it the level of wages, improved sharply during the First World War, but labour relations had by then become unsatisfactory. In 1920 a Trade Board was established for the industry and minimum time rates were introduced, together with a list of minimum piece-work prices to cover the 30 - 35 per cent. of the labour force (principally winders, weavers and bag-sewers) then paid on a piece-rate basis. The initial Trade Board rates (*e.g.* 50s. for an adult male for a 48-hour week) marked a slight advance over those ruling before the establishment of the Board, but, with the end of the post-war boom and the return of severe European and Indian competition, first in export and later even in the British home market,

the minimum Trade Board rates declined until at one time the minimum adult male rate fell to under 35s. per week of 48 hours.[3]

The very severe depression experienced by the industry in the years about 1930 (when unemployment rates rose almost to the 50 per cent. level) was undoubtedly an important factor in preparing the way for the adoption of a new wages-structure after the Second World War. The period of intensive competition and very low profits, which resulted in the withdrawal of a substantial number of firms from the industry, compelled the surviving producers to come together and develop an effective system of collective action in an endeavour to fix minimum prices for manufactured jute goods and to secure some form of Government assistance for the industry. This development was to prove important when, after a number of years of moderate prosperity during the Second World War, the industry was investigated by a Working Party in 1946-47. After a detailed study of the industry the Jute Working Party made some nineteen recommendations. The most important recommendation was that the industry should be granted an extension of the protection from low-cost Indian competition which had accrued to the Dundee manufacturers as an indirect result of the establishment of a war-time control for the industry.[4] Other leading recommendations were that 'the industry should improve working conditions; review the wages structure; and further harmonious relations between management and workers',[5] and 'that the most economical methods of staffing the machinery used by the industry should be fully explored'.[6]

For a variety of reasons the industry was disposed to devote particular attention to the latter recommendations. First, in the late 1940s the industry found itself suffering, for virtually the first time in its history, from a severe shortage of labour—a marked contrast with the

[3] Dorothy Sells, *The British Trade Board System* (1923), pp. 94-100. Throughout the inter-war period the Jute Trade Board minimum time rates for adult males were generally among the lowest sanctioned by any Trade Board, while the minimum female time rate, though not the lowest, lay well towards the bottom of the range. In terms of earnings, however, the relative position of the jute workers was rather more favourable. In October 1935, the average weekly earnings of males (over 21) and females (over 18) in jute were 48s. 10d. and 32s. 5d. respectively, compared with 49s. 9d. and 28s. 8d. respectively for males and females in cotton, 55s. 3d. and 31s. 3d. in woollens and worsteds, and 63s. 8d. and 32s. 1d. in the food, drink and tobacco industries. *Ministry of Labour Gazette*, Vol. XLV, pp. 47, 88, 133, Vol. XLIV, p. 359, Vol. XLVII, p. 46, etc.

[4] *Report of the Jute Working Party* (H.M.S.O., 1948), pp. 4, 69-74, Recommendation 1—'That the industry should be given an assurance now that it will be suitably protected in the home market, when it is again subjected to competition from Indian goods manufactured by labour with much lower wage rates than those obtaining in this country, on condition that firms owning in the aggregate not less than 100,000 spindles are formed into groups . . . .'

[5] *Ibid.*, pp. 5, 93-8, Recommendation 11.

[6] *Ibid.*, pp. 5, 85-9, Recommendation 7.

superabundance of workers which had characterised the inter-war period. This shortage, with its complements of very high rates of labour turnover and much general unrest, originated in the two concentrations of the industry enforced by the Government in 1941 and 1942 to free labour and factory space for urgent war demands,[7] and it was accentuated by the introduction into Dundee in the war and immediate post-war years of a number of new industrial plants which offered financial rewards and working conditions markedly superior to those generally available in jute.

To meet this situation the industry embarked on the radical improvement of working conditions and, in addition, conceded a number of percentage increases to the existing Trade Board (later Wages Council) rates. But any serious endeavour to make jute wages fully competitive by raising the industry's basic time rates would inevitably have involved the industry in a very heavy increase in unit wage-costs. In these conditions, then, the general adoption of some type of payment-by-results scheme comparable to those in use in the new light-engineering plants had much to commend it.

Secondly, an important consequence of the Working Party investigation was that it provided the employers with statistical confirmation of their belief that 'average output per spindle, and average output per worker in the spinning and weaving sections of the industry' had fallen substantially below the pre-war levels.[8] One of the major causes of this decline was the widespread dissatisfaction with the structure of relative wage differentials originally incorporated in the Trade Board structure in 1920. Most employers agreed that, because of the complex of minor technical and operational changes, and the special additions to the Trade Board minimum wage rates introduced during the inter-war and war years, the industry's old wages-structure had become the cause of much dissatisfaction and so of low labour productivity. In addition they agreed that it had begun to exert an unfortunate distorting influence on the relative availability of labour for different jobs in the industry.

Thirdly, immediately after the Second World War the jute industry embarked on an extensive programme of modernisation and re-equipment which, frequently revised upwards, has involved the expenditure up to date of nearly £9 m. Because of their heavy capital commitments, the employers strongly favoured the replacement of the old wages-structure by a new system containing a strong incentive element conducive to the full utilisation of the industry's new high-cost plant.

[7] *Ibid.*, pp. 13-6, 43-5.
[8] *Ibid.*, pp. 85-9.

Further, the employers felt that the new structure should be introduced on an industry-wide basis, if at all possible, partly because they tended to deprecate the competitive bidding-up of earnings, but principally because they wished to minimise the problems and costs involved in introducing an incentive wage-system into the industry's forty to fifty establishments.

For all these reasons the jute employers were favourably disposed to the Working Party's proposal for a revision of the industry's wages-structure. In this project they were fortunate to secure the ready co-operation of the officials of the trade unions catering for jute workers, chief among them the Union of Jute, Flax and Kindred Textile Workers, who were at least as anxious as the employers to secure a revision of wage differentials, and who readily accepted the fact that, in the long run, higher earnings could be secured only from a new wages-structure which provided operatives with an effective inducement to high productivity.

II

The New Wages-Structure

Formal discussions between the Dundee employers, organised in the Association of Jute Spinners and Manufacturers, and the three trade unions which represent the textile operatives in the industry, began in November 1950, a firm of industrial consultants being called in at an early stage to act as expert advisers. It was speedily agreed that the best approach was to classify and evaluate the various jobs in the industry in order to provide a new structure of basic time rates, and then to erect on these basic rates an effective system of incentive bonuses.

In practice the development of the new wages-structure fell into three clearly-defined stages: (i) the classification of all the textile jobs in the industry, and their subsequent ranking through the industry-wide application of a system of job evaluation ; (ii) the conversion of these rankings into money terms to give a new structure of hourly and weekly base rates for each job in the industry, and the addition to these new basic time rates of an agreed incentive element payable to all operatives who completed the standard tasks allocated to them by trained work-study personnel ; and (iii) the actual introduction of this new wage system into the forty or so plants in the industry, with all the problems which this involved.

Under the guidance of the firm of industrial consultants, the first stage—job evaluation—began late in 1950. First, detailed descriptions

of all the textile jobs in the industry were collected from each of the firms in the Association, and from these data a precise specification of each of the 200 and more jobs in the industry was prepared and an official title agreed for each job.[9] Next, the consultants provided a basic rating scale by means of which each job could be rated in terms of each of seventeen characteristics, grouped under the four general headings of (I) Skill, Training and Experience, (II) Responsibility and Mental Requirements, (III) Physical Requirements, and (IV) Hazards.[10] This scale laid down a range within which points could be awarded for each characteristic, these ranges being weighted in such a way that the maximum number of points which could be awarded for characteristics under the first heading (Skill, Training and Experience) was substantially higher than for most of the characteristics under the remaining headings. Using this scale the actual evaluation of the various jobs was carried out by mixed committees of management, supervisors and operatives. In all, some 504 individuals participated in this work, evaluating jobs in forty-five separate establishments and making a total of 111,744 individual assessments. And while a small proportion of these assessments had to be rejected as erratic, the great bulk of them was consistent and confirmed the belief that, given a simple rating scale, the majority of industrial workers can be relied on to make sound evaluations of other people's jobs.

The collation of these assessments yielded an agreed points rating for each of the 200 or so jobs in the industry. The ratings range from just over zero for relatively straightforward jobs requiring little in the way of experience, skill or special aptitude, *e.g.* sweepers, barrowmen, bobbin cleaners, to maxima of thirty to fifty points for such relatively

[9] These titles and specifications are set out in the pamphlet *Jute Wages Structure, 1952,* published by the Association of Jute Manufacturers and Spinners, Dundee.

[10] The characteristics taken into consideration were as follows.

I. *Skill, Training and Experience*

(1) Learning period
(2) Mechanical ability
(3) Previous experience
(4) Complexity of process
(5) Dexterity and motor accuracy

II. *Responsibility and Mental Requirements*

(6) Material or equipment
(7) Effect on subsequent operations
(8) Team work
(9) Alertness to detail
(10) Attention to orders, drawings, etc.

III. *Physical Requirements*

(11) Monotony
(12) Abnormal position
(13) Abnormally heavy
(14) Disagreeableness

IV. *Hazards*

(15) Disease
(16) Accident
(17) Internal injury

skilled jobs as those of weavers and tenters (*i.e.* loom-tuners). To these job pointages there were added 100 arbitrary points in the case of male operatives, and 70 arbitrary points in the case of female operatives, in order to preserve traditional sex differentials.[11] Thus the final ratings range from a minimum of just over 100 to a maximum of 150 in the case of male workers, and from just over 70 to around 100 for female workers.

The first step of the second stage was the conversion of these points figures into monetary terms in order to obtain new basic time rates for each textile job. This was done by preparing an analysis of current wages under the old wages-structure, plotting the results, and then fitting in the points ratings in such a way as to obtain a new base-rate wages-curve which would give a general level of new basic rates slightly higher than those paid under the Wages Council scales. Next, a second scale—officially termed ' fully redeployed earnings at standard performance '—was worked out at 33⅓ per cent. above the new base-rate levels to provide a schedule of target earnings which operatives of average ability should be able to earn when working in such a way as to complete the standard tasks set for them by time-study personnel.

While the preparation of these data was under way, representatives of the employers and trade unions were engaged in drafting the agreement which was to govern the application of the new wages-structure. This agreement, finally signed on 6th November 1952, sets out the conditions which must be complied with before the new wages-structure can be introduced into any establishment.[12] Thus it provides that ' the application of any scheme under this Wages Structure within any individual establishment shall be conditional upon its acceptance by the employer and the Association of Jute Spinners and Manufacturers on the one hand and those employees actually concerned and their signatory unions on the other hand ', and that the new wages-structure can be applied only to ' workers who are proved by scientific work measurement, carried out by a firm of recognised Industrial Consultants or by competent staff trained and approved by them, to be

[11] The official list of job titles and specifications in the pamphlet *Jute Wages Structure, 1952* lists in all some thirty-nine jobs which can be performed by either male or female operatives. In practice, however, it is rare to find males and females performing the same job in the same plant at any one time, although males are, of course, frequently engaged for night work for plant operated by female labour during the day.

[12] The official agreement, together with an explanatory memorandum, is published in *Jute Wages Structure, 1952* (4th edition), pp. 1-7.

fully loaded and adequately deployed'.[13] In addition the agreement embraces a provision to cover the problem of older operatives no longer able to accept full work-loads; a procedure for deriving the base rates and redeployed earnings of juvenile operatives from the adult figures; and a detailed scheme for the protection of the earnings of those few operatives who earned more under the old wages-structure than under the new system.

Once this agreement had been signed the industry was in a position to embark on the third and most complex stage in the development of a new wages-structure [14]—the actual introduction of the new rates in individual plants and departments. This must be, of necessity, a relatively slow process since it involves the expenditure of much time on the making of detailed work studies of the operations to be affected, the preparation of a comprehensive schedule of proposed changes for submission to the joint committee of employers and trade union representatives which controls the operation of the scheme, and, most important, explaining the proposed changes to the operatives concerned and securing from them the explicit consent which is an essential preliminary to the introduction of a new wages system.

Initially progress was slow, partly because of the financial and other difficulties which even the most progressive firms had to overcome in developing and introducing pioneer schemes, and partly because operatives and employers were, not unnaturally, unwilling to be the first to abandon the familiar framework of the industry's old wage system for the complexities and uncertainties of the new structure. By the end of 1953, however, a number of pilot schemes had been introduced in a representative range of firms throughout the industry. Thereafter, as the operatives and employers not immediately

[13] The following official definitions are set out in 'Notes of Interest to Members (Rates of Wages, Working Conditions, etc.)', in an appendix to the *37th Annual Report of the Committee of the Association of Jute Spinners and Manufacturers.*

'(*a*) *Work Load.*—The actual amount of work allocated to an operative at a particular rate of performance. At standard performance an operative is loaded to 80 A.M.s per hour and could be termed "Fully Redeployed".

(*b*) *Allowed Minutes.*—An A.M. is a concept of a minute of work undertaken by a normal skilled operative working diligently in an easy rhythmical manner with due allowance for fatigue, such that 60 A.M.s undertaken in 1 hour would be equivalent to time rate performance, and 80 A.M.s undertaken in 1 hour would be equivalent to "Standard Performance".

(*c*) *Standard Performance.*—A rate of working equivalent to 80 Allowed Minutes per hour on which the "Fully Redeployed" earnings are based.'

[14] 'The Association of Jute Spinners and Manufacturers is predominantly a Dundee organisation and represents firms owning about 80 per cent. of the spindles and 63 per cent. of the looms in the industry'. *Report*, p. 27. Firms which are not members of this Association are encouraged to introduce the new wages-structure, provided they obey the terms of the official agreement governing the scheme.

affected came to see that those of their fellows who had accepted redeployment were deriving substantial benefit from it, support for the new structure increased and the number of schemes submitted to the joint committee of employers and trade union representatives rose sharply.

For a variety of reasons—economic, technical and sociological—it has rarely been possible to introduce the new wages-structure into all departments of a firm or establishment simultaneously. In general firms have introduced the new structure in a series of stages, concentrating first of all on those processes where the greatest advantages can be obtained or where the difficulties of introduction are least. Thus while the most recent figures show that at present some 30 - 35 per cent. of all textile operatives attached to the jute industry are paid under the new wages-structure, this does not convey a true picture of the progress made ; the ranks of these redeployed operatives include a substantially higher proportion of all the direct production workers at the main stages in jute processing. Thus a high percentage of the operatives in the spinning section, recently re-equipped with high-speed frames, are on the new structure, as are a substantial majority of the operatives in the weaving sheds, where the introduction of the new circular looms, and the attachment of automatic devices to old flat looms, has recently been undertaken on an extensive scale. Progress in other sections, notably preparing and winding, has been less rapid, partly because many firms are still awaiting delivery of new plant recently developed for these processes, and partly because in a number of firms the operatives in these sections can earn almost as much, and in some cases more, from the old Wages Council piece-rates than from the rates provided in the new wages-structure. Other factors which have impeded the introduction of the new system include the presence in the industry of relatively large numbers of older operatives, many of them weavers, who cannot, or will not, readily accept the new and somewhat heavier work-loads attached to the new wages-structure; the scarcity and high cost of the skilled consultants needed for the making of work studies and the preparation of schemes ; and the very heavy burden which the preparation and introduction of these schemes imposes on all levels of management. Nevertheless, there is good reason to believe that the preparation of new schemes will continue at the present rate for some years to come. It therefore seems probable that, at the end of another five or ten years, only a few relatively small groups of employees will still be paid on the Wages Council scales.

III

An Assessment of the New Wages-Structure

It remains to consider the advantages which have accrued to the operatives and employers in the Dundee jute industry as a result of their acceptance of the new wages-structure, and to examine the merits, and the possible defects, of this particular method of wage payment.

The principal advantage of the new system to the operatives is, unquestionably, that it has enabled the great majority of those time-rate workers who accepted redeployment to earn approximately one-third more than they would otherwise have done, while redeployed piece-workers have received a rather smaller, but still substantial, addition to their earnings. Thus while the minimum Wages Council time rates for the British jute industry are still relatively low, redeployed workers are in many cases quite well paid, with, for example, substantial numbers of young female weavers of eighteen and nineteen regularly earning £8-9 per week of forty-five hours.[15]

To the employers, also, the new wages-structure has brought substantial benefits. Dundee jute firms now find that, with higher levels of operative earnings, it is much easier to recruit and keep labour, and that the quality of the labour they get is tending to improve.[16] Because the new wages-structure has led, through the rationalisation of workloads, to a substantially higher level of machine utilisation and a marked rise in labour productivity, this improvement in the labour position has involved only a relatively slight increase in their wage bills. Indeed, wage costs per unit of product have in general fallen, in some cases by a substantial margin, thus enabling firms to absorb

[15] The average weekly earnings of all female jute workers (aged 18 and over) in the last pay-week in October 1955, were 118s. 3d. for an average week of 42·9 hours. Comparative figures are: cotton, 121s. 9d. for 41·9 hours; woollen and worsted, 116s. 5d. for 41·7 hours; food, drink and tobacco, 109s. 5d. for 43·0 hours; and all manufacturing industries, 116s. 0d. for 41·8 hours. *Ministry of Labour Gazette*, Vol. LXIV, pp. 82-9.

Additional advantages have accrued to the operatives from the new wages-structure as a result of the removal of the old anomalies in the relative wages for different jobs; former piece-workers now find it much simpler to keep track of their earnings.

[16] Employment in the jute industry in Scotland rose from 18·1 thousands in June 1949 to 21·1 thousands in June 1954, with temporary falls to 17·6 thousands in 1950 and 1952; in 1955 employment fell to 20·0 thousands (*Digest of Scottish Statistics*). In recent years the improved earnings under the new wages-structure have been important in enabling the industry to secure a better grade of labour. In particular the new structure has done much to facilitate the recruitment of young female labour for the weaving sheds, thereby reducing the dangerously high average age of the industry's female workers in the immediate post-war years.

part of the rise in other costs over the last two or three years.[17] In addition the new wages-structure has greatly simplified the problem of fixing wage-rates and manning-schedules where new machinery is introduced—a major advantage in an industry where re-equipment is proceeding rapidly. Further, the introduction of an incentive bonus system to departments formerly on time rates has had the usual result of generating strong operative pressure for greater managerial efficiency in the control of work flow, with the consequent elimination of irregularities in the rhythm of production. Finally, in at least a number of firms the new wages-structure has led to an important improvement in labour-management relations in that a growing body of operatives now feel that they are, in the words of one executive, at last getting ' a fair crack of the whip '.

In conclusion, it remains to advance a few general, and very tentative, reflections on the wider implications of this, the first experiment in overhauling the wages-structure of one of the older British industries. A word of caution is necessary. A wages-structure is not something which can be considered in isolation from the industrial, economic and social context from which it stems. This is particularly true in the case of the Dundee jute industry—a trade with strong hereditary and traditional links with the past, highly localised in one small labour market, and relatively isolated from some of the major economic forces at work elsewhere—the more so since this isolation is increased by the protection from foreign competition which the industry at present enjoys as a result of the Government's decision to maintain the restrictions, originally imposed during the war, on the import of manufactured jute goods. There can be no doubt that the concentration and structure of the British jute industry, the traditions of co-operation among its member firms, and the relative uniformity of wages gradually developed over the years, all simplified the task of overhauling the industry's wages-structure.

The new wages-structure is open to three criticisms, two of minor and one (possibly) of considerable importance. First, there are the relatively small points that the wording of the official agreement governing the scheme seems to place a greater emphasis on the ' scientific ' character of present-day work measurement than would most responsible work-study specialists, and that it further obscures the already complex problems of managerial terminology by using a

[17] It was, unfortunately, impossible to obtain precise statistical information on this point, but there is good reason to believe that, in spite of the fact that wages and salaries together account for less than 20 per cent. of total costs, the reduction in unit wage costs as a result of the adoption of the new wages-structure has been of considerable importance.

number of phrases, notably 'merit-rating', in a manner contrary to general usage. Further, the extending application of motion study and similar techniques, which can in certain circumstances lead to quite substantial increases in labour productivity, may well create conditions in which some redeployed operatives can earn substantially more than the standard rate of bonus. This situation will, of course, arise only in those firms which introduce motion study *after,* instead of *before,* the introduction of the new wages-structure. In practice, however, few of the Dundee firms followed the correct procedure here—at least in the early schemes. This failure may well give rise to real problems in the future, and may necessitate some amendment of the original scheme. Secondly, and rather more important, the evaluation of a wide range of jobs in an industry can never be an exact or absolutely precise process. Thus while the method of job evaluation adopted in the jute industry has certainly produced a fairer, more equitable system of wage differentials than that embodied in the old Trade Board rates in 1920, there is no reason to believe that it has, once for all, yielded a structure of relative rates that can be maintained intact for an indefinite period. Thirdly, and most important, the adoption of a wages-structure of the type now being introduced in Dundee involves the permanent stabilisation of wage differentials throughout the whole industry. Thus while the absolute level of wages can be altered readily by means of percentage changes—there have, for example, been two percentage increases in the jute industry in the last eighteen months—once a wage system of this type is installed the fact that it is firmly based on a series of job-evaluation pointages means that it becomes impossible to use changes in the wage rates of particular occupational groups inside the industry to secure changes in the quantities of particular grades of labour coming forward. Any attempt to overcome a shortage of one particular grade of labour by raising the rates attached to it would at once undermine the basic principles on which the whole system depends. In effect a wages-structure of this kind is based upon the implicit assumption that though there may be changes in the general availability of jute workers for the industry as a whole, there will be no disproportionate changes in the availability of the different grades of labour required in the industry—or at least no disproportionate changes which cannot be met by alterations in working conditions, or by the provision of special training facilities to guide the flow of new recruits into the jobs where labour is scarce. In an industry like jute, where there are few textile jobs which require a long training period or demand very high levels of skill or experience, this underlying assumption may well be valid. It would probably be difficult to extend a wages-structure of this type, in its original form, to industries

where the range of skills and aptitudes required is substantially wider. The engineering, aircraft, motor or shipbuilding industries, for example, would almost certainly find it difficult to stabilise permanently the wage differentials for wide ranges of skilled, semi-skilled and unskilled operatives whose availability was likely to be influenced substantially by changes in market conditions in the economy as a whole.[18]

Whatever the long-term validity of these tentative criticisms of the jute industry's new wages-structure there can be no doubt that this system has, up to date at least, operated smoothly. One important reason for this is the fact that the new wages-structure has not, in general, been introduced on its own, but rather as one of a large complex of changes which has gone far to transform the industry in the last ten years. Industrial sociologists are now well aware that although workers will often fight bitterly against a relatively small innovation which disrupts their established habits and routines, they will show a surprising adaptability to a series of much more far-reaching changes. In the jute industry the introduction of the new wages-structure has gone hand in hand with extensive re-equipment, the general improvement of working conditions, and radical changes in the training and abilities of foremen and junior managers. In this connection it is surely significant that the greatest difficulties in introducing the new structure have in general arisen in firms or departments where the change was introduced in isolation. Small firms, which had of necessity to maintain production while installing the new structure or introducing other changes, did sometimes encounter opposition in the early stages. On the other hand, the larger firms, which control a number of plants and could therefore close down a particular works or department for modernisation and re-equipment and introduce the new wages-structure on re-starting production there, found their employees ready to accept the new system of wage payment as a logical accompaniment of other changes introduced at the same time.

The fact that the introduction of the new wages-structure has, in almost every case, been accompanied by other changes in machinery, methods of working, supervision, etc., means that it is extremely difficult to arrive at even a tentative estimate of the precise increase in labour productivity which may fairly be attributed solely to the the change in the wages-structure. The limited evidence available from the small number of cases where the new structure was introduced into weaving sheds without any obvious changes in the other factors in the situation suggests that labour productivity rose, after a short

[18] A limited element of elasticity is, of course, available in the shape of the introduction of new jobs where technical changes make this necessary.

shake-down period of a few weeks, to a new level at least 35 per cent. above that secured under the Wages Council rates. And some of the industrial consultants and work-study personnel most intimately concerned with the introduction of the new structure maintain that, on average, labour productivity rose by at least 35 per cent. wherever the new system was applied, while in a number of instances the improvement in productivity was very considerably greater.

Certainly there can be no doubt that the new structure has resulted in a substantial increase in labour productivity, has enabled the industry to pay considerably higher wages, has greatly simplified the introduction of new plant, and has provided incontrovertible evidence that in many cases the productivity of existing plant can be very substantially increased when the full co-operation of the operatives is secured. In consequence the industry is well pleased with its experience of the new wages-structure, and attempts are now being made to develop a similar type of scheme for the industry's maintenance workers.

These results, together with the fact that this innovation in the jute industry has aroused considerable interest in a number of other British industries—including in particular one of the major textile trades—suggest that in the long run this Dundee experiment may well prove to be of very substantial value. But any assessment of the relevance of the jute industry's success in this field must take account of four important factors—the limited size of the industry, its marked geographical concentration, the relative uniformity of wage rates and earnings prior to the introduction of the new wages-structure, and the ready spirit of co-operation which existed both among individual employers and between the employers as a whole and the textile trade unions. Where these conditions are not fulfilled, the difficulties which would arise in the introduction of a wages-structure of this type might well be substantially increased. Nevertheless the success of the Dundee scheme is certainly important. It may well serve as a sort of laboratory experiment for those major British industries which are currently trying to escape from the toils of out-of-date systems of wage payment.

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THE DUNDEE SCHOOL OF ECONOMICS

In Memoriam

The Dundee School of Economics, which lived for exactly twenty-one sessions before it was absorbed in the new School of Social Sciences of Queen's College, St. Andrews, made for its size a most distinguished contribution to the development of modern economic thought. This is evident in the names and varied interests of those who taught there, of whom six have contributed to the memorial volume of *Economic Essays*.[1] At its post-war peak it had some sixty students reading for London B.Com. and B.Sc.Econ. degrees, a high number for Scotland where the specialised study of economics is cramped. The contributions to this volume show what might be regarded as a 'London' approach to economics, at least to those who accept Professor A. L. Macfie's definition of the 'Scottish Tradition'.[2]

It is not in fact clear that this Scottish tradition has survived from the early years of the nineteenth century in the field of economics, though no doubt Scottish universities maintained a longer addiction to obscure German prophets than others did. It is not obvious that the contribution of Scotland to economics in the last thirty or forty years has been largely 'historical, social or semi-philosophical', or 'speculative', or 'normative'.[3] But in so far as Scottish universities have sometimes shown themselves allergic to the London-Cambridge approach, the significance of the Dundee School is that, whether regarded as a foreign irritant in the Scottish oyster, or merely as a faithful carrier of the new traditions of economics, it has made it more difficult for Scots to forget that, though we need a wider economics that goes beyond curves and limited assumptions, such a wider economics must be built on the foundation of careful analysis that our fathers so painfully laid. The six essays of this memorial volume (four on fundamental economic theory and two on economic history) show something of the nature of the bricks that make such a foundation. It is to be hoped that, though the Dundee School lives no more as such, the influence of this tradition will penetrate deeper into the Scottish universities.

[1] *Economic Essays, in Commemoration of the Dundee School of Economics, 1931-1955*, edited by J. K. Eastham (1955: distributed by the Economists' Bookshop Ltd., London).

[2] 'The Scottish Tradition in Economic Thought', *Scottish Journal of Political Economy*, June 1955.

[3] *Ibid.*, pp. 99, 101.

Professor Duncan Black's essay on 'Wicksell's Principle in the Distribution of Taxation' provides an interesting summary and critique of a part of Wicksell's work not yet translated into English. In this, Wicksell touched on a field on the border-line between economics and politics that should interest Scottish devotees of 'political economy'. He based his theory of taxation on the benefit gained from government expenditure. Taxes must therefore be linked with expenditure, and expenditure with taxes. Wicksell was not happy about the 'tyranny' of the chance majority of a people's assembly, and, like Robbins,[4] had a hankering for the purer democracy of the market, though it is to be noted that in Wicksell's time the danger was over-taxation of the poor by an assembly over-representative of the rich—he did, however, foresee the opposite danger. He therefore proposed that voting on taxation and expenditure should always be linked, and that a special majority should be required to increase taxation and a minimum minority to abolish it. The actual voting would require a large number of linked motions, and Black proceeds to show the three main difficulties involved. (1) The proposal clearly offends on grounds of general equity in the power given to extreme minorities. With a 90 per cent. special majority, 11 per cent. can always block anything. The tendency is therefore to reduce state expenditure and taxes. (2) If members' preferences for taxation-expenditure proposals are complementary, that is to say if members will vote for A if B is already in existence, but not if C is the case, then clearly we require a prior decision as to the order in which proposals are taken. We return to the familiar wrangle about the order of the agenda. (3) There is the case where several proposals are passed by the special majority. Wicksell wrote 'if several obtained the special majority the decision might be made in one way or another (and the simplest way seems to be by the comparative majority of votes)'. Black interprets this to mean that, if, with an existing situation A_0 and proposals A_1 and A_2, voting (with a special majority of 90 per cent.) results in 90:10 for A_1 as against A_0, and 100:0 for A_2 as against A_0, then A_2 is chosen. It is very obvious that this result is quite compatible with a vote of 90:10 for A_2 as against A_1. To prove these points Black uses a number of diagrams and makes rather heavy weather. Anyone with a practical knowledge of committee procedure knows that there may be a larger vote against an amendment than for the substantive motion, or that amendment A may get a larger majority in Bill B than in Bill C, though Bill C is preferred to Bill B. What is clearly needed is a series of knock-out votes. Wicksell might merely have meant

[4] *The Economic Problem in Peace and War* (1947), pp. 11-28.

in the passage quoted that, *in the subsequent votes* between A_1 and A_2, a simple majority was required (though he does use the word 'comparative').[5]

Mr. J. K. Eastham wrestles with one of the major issues of economic confusion in 'A Redefinition of the Boundary between Interest and Profit Theories'. His 'remapping from a new base' of 'a well trodden piece of country' is suggestive and illuminating. It is in the failure to produce a satisfying analysis of interest and profit, two of the fundamental sources of income, that modern neo-classical theory has proved most disappointing, and in this failure lies the most common cause of scepticism about economics. Mr. Eastham clearly sets out the 'bricks' we have to deal with: the productivity of investment, the tendency to accumulate, time preference, liquidity preference, and the propensity to take risks. His scheme is a happy marriage of Schumpeterian and Keynesian analysis. Schumpeter's theories are clearly unsatisfactory as they stand, and his reactions to Keynes were perverse; and Keynesian theory has never come to grips with profits. Eastham links profits fundamentally with the rate of accumulation: 'considerations of time preference and of uncertainty modify a relation between investment and rate of accumulation which would exist in their absence although they would not give rise to any income elements in the absence of a desire for accumulation.' 'Uncertainty is not necessary for profit to emerge.' On the interest side of the fence we have liquidity preference, and nothing else; the savings side of the matter is taken account of in the desire to accumulate. Risk complicates the accumulation function, and prevents any simple mathematical model from being useful; it is here that current theories show the biggest gap for future analysts. At the centre of Eastham's scheme is 'the investor as an entrepreneur immobilising the real resources of the community' so as to 'take advantage of an investment opportunity', rather than 'the investor as parting with liquid resources to purchase equity securities'. This is the fundamental point where Schumpeter and Keynes meet. Most puzzling at first sight may seem to be Eastham's refusal to allow time preference, uncertainty, and the desire to accumulate, to be included in the interest part of the map. But what clearly emerges is the distinction between the points of view of the individual and of society, which has confused so much of the discussion in this field. In the case of a society with no accumulation individuals can turn present consumption-goods into claims against future consumption-goods, but no collective saving takes place.

[5] Fig. 2 on p. 14 reads 'Expenditure on Item' for the vertical axis, whereas it should read 'Order of Preference'. The sentence at the top of p. 19 seems to have gone adrift.

Eastham regards this exchange of claims as a matter of liquidity preference, and from the point of view of society as a whole we must agree. But liquidity preference involves uncertainty, which can exist even without accumulation (agricultural yields may fluctuate unpredictably because of the weather). Even if there is no uncertainty in a static state, a rate of interest may emerge, because of the dispersion of individuals' time preferences.[6] The time preferences and uncertainties of individuals are important in a society where collectively there is no saving and no risk-taking ; individuals can accumulate in response to interest-rate changes, though the collective rate of accumulation is determined by the entrepreneur and his accumulation function. The importance of Mr. Eastham's article can perhaps be seen from these brief comments.

Mr. J. C. Gilbert writes on ' Professor Hayek's Contribution to Trade Cycle Theory ', with particular reference to the upper turning-point. He believes that Hayek has described an important, though not the only, cause of the down-turn, and has stressed factors neglected in other analyses. He deals in detail with the analysis in *Prices and Production,* and with Hayek's later formulation of the Ricardo effect, which Gilbert believes to be inferior to the earlier. The article provides a useful summary of Hayek's views on this problem in the light of Keynesian and later theories, and also of Hayek's critics. While it makes all the important criticisms of Hayek, it greatly exaggerates, in my view, Hayek's importance. Gilbert thinks that Hayek's work was nearer to dynamic economics than that of Keynes, and that his ' particular emphasis on the immobility of labour and the heterogeneity of capital goods is of vital importance '. Modern Keynesians would hardly deny the importance of these factors, and it is somewhat strange that Gilbert neglects Rostow's work and Kaldor's extremely important 1938 article on ' Stability and Full Employment ' which deals precisely with these factors among others.[7] Gilbert believes that Hayek ' exaggerated the degree of rigidity of the capitalistic structure of production '. The discussion about the Ricardo effect brings out the crucial importance to Hayek of ' the decrease in capital intensity of investments during the later stages of the boom ' in offsetting any widening of capital, so as to bring about an actual decline in investment. I must admit to finding this discussion of the period of production and capital intensity extremely academic and unrealistic ; when all the proper qualifications

[6] See E. V. Morgan, ' Some Thoughts on the Nature of Interest ', *Oxford Economic Papers,* June 1949.

[7] Reprinted as Ch. 33 of *Readings in Business Cycles and National Income,* edited by A. H. Hansen and R. V. Clemence, and Ch. 14 of *Readings in Economic Analysis,* edited by R. V. Clemence (Vol. i).

have been made, as Gilbert does make them, we are not left with much of value. Perhaps the main difficulty is precisely because Hayek's analysis is too general, and too much phrased in terms of aggregates, though Gilbert thinks he has an advantage here over Keynes. Rather than any general discussion of 'the time dimension of investment', what seems important is the shifting of investment from one industry to another, from one project to another, from raw material stocks to work in progress, from machines to factories. It is not obvious that in analysis of this concrete kind the Hayekian system is more useful than the Keynesian.

Professor T. H. Silcock writes a closely-argued analysis of 'Advertising Costs in Monopolistic Competition', which falls largely within the tool-making category. He re-interprets Chamberlin's 'large group' case with high cross-elasticities of supply and with prices equal to average cost but without homogeneous demand conditions. He then introduces the diagrammatic representation of selling costs of the type that alter the market rather than the product, and are an alternative to price-cutting. Price *minus* selling cost is set against an average production-cost curve by means of the 'Lerner-Smith locus'. From this it is possible to deduce certain consequences of advertising expenditure. It can be shown that it is likely that advertising will increase the scale of production, though not necessarily reducing either the number of firms or sale prices. His final conclusion on the effects on standardisation is that 'advertising functions of the most likely form will give economic inducements to either conformity or eccentricity at the expense of more moderate and varied self-expression'. This is an article for the hardy-minded enthusiasts for modern theories of the firm.

Professor R. H. Coase on 'The Postal Monopoly in Great Britain' gives us a further fascinating survey of an aspect of the history of the Post Office, which he has made his own particular field. The difficulties that beset academic critics of established institutions of the size and importance of the Post Office are shown by the revealing fact that the files relating to the case of the Oxford and Cambridge Colleges in the 1870s and 1880s 'are still regarded as confidential and are not available for study'. Whether Coase's general attitude to such a monopoly as the Post Office is accepted or not, there are plenty of reasons for disquiet, not least among them the facts that the postal monopoly was originally designed so that Government officials could read the letters of would-be seditious characters, and that the Post Office still retains the right to open letters under warrant from a Secretary of State; more disturbing than the existence of the right is the fact that little is known about the extent of its use.

Mr. S. G. E. Lythe has produced a most careful and detailed study of 'Scottish Trade with the Baltic, 1550-1650' in which he makes the best possible use of what quantitative information is available from the Sound Toll Registers, and builds up, as far as it is possible, a picture of Scottish trade with that area. A mere layman in such matters can make no comment, except to regret that our ancestors were so careless in failing to keep the records which alone could give us a full picture of how they lived.

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CURRENT TOPICS

THE third Annual General Meeting of the Scottish Economic Society will be held in the College Rooms, The University, Glasgow, on Wednesday, 20th March 1957. Tea will be served to members at 5.15 p.m., and the business meeting will begin at 5.45 p.m. After the formal business, the President, the Rt. Hon. Lord Bilsland, K.T., M.C., will address the Society.

The following note on social and economic research in progress at Aberdeen is the third in the series for the Scottish universities. Notes on work at Glasgow and Edinburgh were published in Volume III, No. 1, and Volume III, No. 2. Anyone who wishes more detailed information about research at Aberdeen should write to the Secretary, The Scottish Economic Society (Mr. T. A. F. Noble, Department of Political Economy, King's College, Aberdeen).

Those who read the note on the *Third Statistical Account of Scotland* in Volume II, No. 3 (October 1955) will know that Aberdeen University has accepted responsibility for editing and preparing for publication the accounts of the northern counties, from Aberdeen and Kincardine to the Outer Hebrides in the west and to Orkney and Shetland in the north. Up to date, the main work has been on the counties of Aberdeen, Inverness, Caithness and Sutherland, and it is hoped to have ready for publication in 1957 the volume on the county of Aberdeen, and in 1958 the volume on the county of Inverness.

Publications within the last year include a book on the relation of ethics and economics, and articles on the economics of hydro-electricity, on economic progress in underdeveloped areas, and on problems of economic growth in Scotland in the eighteenth and nineteenth centuries. Work on the last two of these subjects is continuing, and includes a detailed examination of Leverhulme's schemes in Lewis and Harris as a case study in the problems of underdeveloped areas. Research is in progress on the economics of home ownership, on an economic evaluation of the Forestry Commission's policy in Great Britain, as well as on maximum likelihood estimates for Törnqvist demand curves.

The manuscript correspondence and official papers of leading British statesmen of the period 1765 to 1815 are being examined with special reference to economic and social issues. Other work in economic history includes the social and economic aspects of social medical activities from 1740 to 1840, and a study of economic growth, stagna-

tion and change in Kettering, including its evolution from a wool town to specialisation in shoe manufacture.

In agricultural economics, work has recently been published on farm rents and on post-war trends in the size of Scottish agricultural holdings, as well as on the history of some early agricultural improvers. The present state of the livestock trade in Aberdeenshire is currently under examination.

RECENT ECONOMIC TRENDS

Scottish Banking Trends, 1950-56

In this note there are described, very briefly, certain movements in the assets and liabilities of Scottish banks from 1950 until the autumn of 1956. Most of the figures used are drawn from two sources, the annual balance sheets of the banks and the half-yearly statements displayed in their branches by five of the six banks. The balance sheets appear on different dates in a period extending from September to February, and aggregates based on them must accordingly be treated with caution. With the half-yearly statements the spread of dates is comparatively slight, two to three weeks being the usual period.

Table I

DEPOSIT AND NOTE LIABILITIES, AND ASSETS, 1950-55

(£ millions)

Year[1]	Deposits	Notes	Cash	Money at call	Bills	T.D.Rs	Investments	Advances
1950	760	71	...[2]	...[2]	...[2]	21	410	188
1951	748	76	96	69	21	8	361	231
1952	761	85	104	88	30	—	367	211
1953	782	92	109	82	24	—	398	206
1954	833	98	116	85	28	—	413	228
1955	775	105	121	87	28	—	363	214

[1] In each case figures are totalled from balance sheets appearing between September of the year indicated and February of the following year.

[2] No totals are shown because one bank lumped together all liquid assets in its 1950 balance sheet.

Table I shows the movements of various types of assets and liabilities, as shown in five cycles of annual balance sheets, 1950-51 to 1955-56. This covers the period that saw the revival of the use of monetary weapons, and it finishes at the end of the first year of the current credit squeeze. Some interesting points emerging in this period are discussed below.

1. *Liquid assets.* Cash holdings have increased steadily throughout the period, both absolutely and relatively to deposits. The cause of this is the rise in note circulations; these have risen in line with the general expansion of currency, and with the trend to a higher ratio of circulating media to bank deposits. Bills and money-at-call have

increased, and these two items have both stood somewhat higher as percentages of deposits than in the five years before 1950. This change must bear some relation to the new monetary climate ; it must be considered together with movements in risk assets.

2. *Risk assets.* In 1951, with the onset of the new monetary policy, the post-war growth in Scottish bank advances was halted and reversed. Since 1948 this growth had been in part at the expense of investments ; but with the restriction of advances under the new policy investments began to rise again, though between 1951 and 1952 the rise was very slight. In reducing advances between 1951 and 1952 the banks appear to have moved into short assets rather than securities, possibly because of a combination of uncertainty, caused by the new policy, and bearishness about gilt-edged. The upward movement in advances was resumed in 1954 ; in the following year all risk assets fell, investments sharply so.

If we compare the movement of Scottish advances with those of the London Clearing Banks (using the end-year totals for the Clearing Banks because of the concentration of Scottish balance sheets in the final quarter) it appears that they moved roughly together (Table II). Scottish advances appear to have been rising more rapidly in 1950-51 ; and up to 1955 they appear to have remained at a higher level than English advances, compared with 1950. However, without fuller data it would be unwise to read too much into these differences.

TABLE II

THE MOVEMENT OF BANK ADVANCES, 1950-55

(1950 = 100)

Year	Scottish banks	Clearing Banks[1]
1951	122	114
1952	112	106
1953	109	103
1954	121	115
1955	113	113

[1] Total advances at 31st December in each year.

THE PERIOD OF THE CREDIT SQUEEZE

Since the end of 1954 Scottish bank deposits have declined in line with the general movement of the British banking system. This fall in deposits resulted from action by the authorities to restrict the volume of liquid assets held by the banks, and it was intensified,

particularly in the first half of 1955, by a movement on the part of big depositors to hold higher-yielding Treasury Bills rather than bank deposits. (Two bank governors mentioned this move in their annual statements.) Changes in deposits in the Scottish and English systems are shown in Table III.

TABLE III

SCOTTISH AND ENGLISH BANK DEPOSITS, 1954-56

Period	Five Scottish banks[1]		Four Scottish banks[2]		Clearing Banks	
	Total	Change	Total	Change	Total	Change
	£ m.	%	£ m.	%	£ m.	%
End - 1954	665·5	—	485·9	—	6,941	—
Mid - 1955	615·2	−7·5	457·7	−5·8	6,510	−6·2
End - 1955	608·1	−1·2	437·2	−4·5	6,612	+1·6
Mid - 1956	568·2	−6·6	418·8	−4·2	6,283	−5·0

[1] The Bank of Scotland, which has no statutory obligation to publish half-yearly statements, is excluded.
[2] These totals exclude the deposits of the Clydesdale and North of Scotland Bank, as well as those of the Bank of Scotland.

In Table III the Bank of Scotland is excluded because it does not publish half-yearly statements. Scottish deposits are given both with and without the deposits of the Clydesdale and North of Scotland Bank because the deposits of the Clydesdale show a very considerable seasonal swing between the December and June statements (with a corresponding swing in liquid assets). This movement is probably connected with accounting practices affecting the make-up of the end-year statement (which coincides with the annual balance sheet). If we eliminate the Clydesdale's deposits the decline in the deposits of the four other banks is seen to be much more evenly spread over the eighteen-month period as a whole. Of course, the end-year figures of the Clearing Banks are themselves subject to a special (inflating) influence owing to their being made up on the last day of the year (only two Scottish banks, including the Clydesdale, make up their statements on this day). However, even allowing for this, it appears that the drop in Scottish deposits, while proceeding at the same rate as in England in the first half of 1955, was at a higher rate in the second half of the year. Over the whole eighteen-month period the drop in the deposits of the four Scottish banks was comparatively greater than in the total of English deposits.

The decline in bank deposits demanded a reduction of assets. In the first half of 1955 the Scottish banks, like the English banks, met this mainly by liquidating investments. In some cases, though not in all, short assets also declined. The movements in the security holdings of five Scottish banks, and of the Clearing Banks, are given in Table IV.

TABLE IV

CHANGES IN THE INVESTMENTS OF SCOTTISH AND ENGLISH BANKS, 1954-56

Period	Scottish banks[1]		Clearing Banks[2]	
	Total	Change	Total	Change
	£ m.	%	£ m.	%
End - 1954	311·1	—	2,353	—
Mid - 1955	288·4	*−7·3*	2,099	*−10·8*
End - 1955	267·3	*−7·3*	2,016	*− 4·0*
Mid - 1956	261·0	*−2·3*	1,963	*− 2·6*

[1] The totals of Government securities and guaranteed stocks shown in the half-yearly statements. The Bank of Scotland is excluded.

[2] As given in the monthly statements; the totals used here are those for 31st December and 30th June.

The somewhat lower proportionate fall in Scottish banks' securities, in the first half of 1955, must be viewed alongside a bigger proportion of securities within total assets. It may however give some slight support to the tentative conclusion (suggested later) that in the first half of 1955 Scottish advances were not rising at so high a rate as English advances.

It is more difficult to trace the course of advances at half-yearly intervals because, of the five banks publishing statements, only three show their loans and advances as a distinct total, the remaining two combining them with various other assets. To construct as full a picture as the available figures allow Table V sets out the figures of all the banks individually, drawing them both from half-yearly statements and from balance sheets. In each case the columns of figures are arranged chronologically from left to right. In the case of the two banks giving composite totals in their statements, corresponding totals are given from their balance sheets in the appropriate column. Finally, for comparison, the mid-year and end-year totals of the Clearing Banks' advances are given.

TABLE V

SCOTTISH AND ENGLISH BANK ADVANCES, 1954-56
(£ millions)

Bank	End-1954	End-February 1955	Mid-1955	Sept.-Nov. 1955	End-1955	End-February 1956	Mid-1956
Royal Bank of Scotland	48·9	—	52·6	—	45·3	—	43·6
Clydesdale and North Bank	47·0	—	48·8	—	42·2	—	41·2
National Bank of Scotland	29·6	—	23·4	23·0	23·3	—	22·1
Bank of Scotland	—	44·3	—	—	—	44·7	—
British Linen Bank[1]	35·7	—	40·7	36·1	35·5	—	36·8
Commercial Bank of Scotland[2]	45·4	—	48·3	48·0	47·7	—	49·8
Total of half-yearly statements	206·5	—	213·9	—	194·2	—	193·5
Clearing Banks' advances	1,897	—	2,186	—	1,851	—	1,975

[1] The totals are of 'other securities': these are presumed to include advances (about two-thirds of the total), cheques in transit, customers' liabilities for acceptances, etc., bank premises, unquoted investments.
[2] The totals are of 'other securities': these are presumed to include advances (about three-quarters of the total), Treasury Bills, bank premises, customers' liabilities for acceptances, etc., shares in a subsidiary company.

Any inferences drawn from these figures must be very tentative, and what follows must be accepted with due reserve. During the course of 1955 English bank advances rose by 15 per cent. in the first half of the year and fell by the same proportion in the second half. The result was that the end-year total was only slightly below that at the beginning of the year. Scottish advances, on the other hand, rose comparatively less than English advances during the first half of the year; but the decline in the second half of the year was markedly greater than the rise in the first half, so that over the year Scottish advances appear to have fallen comparatively more than English advances. If we take the aggregates of the half-yearly totals, disregarding the presence of other assets in the totals of two banks, Scottish advances rose by about 3 per cent. over the first half of 1955. This figure is strongly influenced by the considerable drop in the advances of the National Bank which, at least in its timing, must have been caused by special factors. The average rise for the four other banks seems to have been in the region of 8 per cent. In the second half of the year the proportionate drop in aggregate advances,

shown by the statements, was 9 per cent. In this case the behaviour of the advances of the National Bank causes the average rate of decline to be less than the typical rate. For the year as a whole Scottish advances declined by perhaps as much as 6 per cent. This somewhat greater decline in Scottish advances needs to be studied together with the evidence from Table II that, since 1950 and compared with that year, they have run at a higher level than English advances. However, between the upturn in bank advances towards the end of 1953 and the onset of credit stringency in early 1955, Scottish advances had not been rising more rapidly than English advances.

In September 1956, for the first time, the British Bankers' Association published a breakdown of its quarterly total of British bank advances into Clearing Banks' advances, and Other Banks' advances. As Scottish bank advances account for roughly four-fifths of the total advances of the 'Others' these figures may be examined for indications of trend (Table VI).

TABLE VI

BRITISH BANKERS' ASSOCIATION: ADVANCES

(£ millions)

	August 1955	November 1955	May 1956	August 1956	November 1956
All members	2,215·2	1,980·7	1,985·1	2,002·0	1,930·5
Clearing Banks	1,934·3	1,731·1	1,724·7	1,748·4	1,683·0
Other Banks	280·9	249·6	260·4	253·6	247·5

The divided totals of advances are available only from August 1955 onwards. Between August and November of that year the decline in the advances of Other Banks was 11 per cent.—slightly more than the drop in the Clearing Banks' total. In view of the differences of period and coverage of the two series this is quite consistent with the previous estimate of a 9 per cent. decline in the Scottish banks' advances in the second half of 1955, and in fact it confirms the order of magnitude of this estimate.

It is hazardous to read too much into the movements of figures, especially in the case of the Scottish banks' advances where, owing to the absolute smallness of the totals, the risk of fortuitous changes is relatively high. But the comparison of the movements of English and Scottish advances in 1955 suggests a question which should at least be asked: 'Was the contraction of Scottish advances in the second half of the year disproportionate having regard to the rate of expansion in the first six months?' And this points to a further

question: 'If there are regional differences in the pace of a boom—as there may have been in early 1955—does this perhaps call for some regional discrimination in the application of credit policy where that policy involves the restriction of advances by official orders or requests?'

Since the end of 1955, judging by the B.B.A. figures (which are 'purer' than the monthly and other totals used elsewhere in this note) there have been some divergences of movement between Scottish and English advances, though they are probably not significant. They may well have been caused by seasonal factors of differing weight in the two systems. As this note goes to press the first three of the 1956-57 cycle of Scottish balance sheets have appeared. In each case advances are practically unchanged from the previous year's balance and from the mid-1956 statement, and other assets show practically no change. The deposits of two of the banks have increased over the previous year, but the third shows an offsetting decrease. The new figures strengthen the impression that during 1956 there has been little change in major balance-sheet totals of the Scottish banks.

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